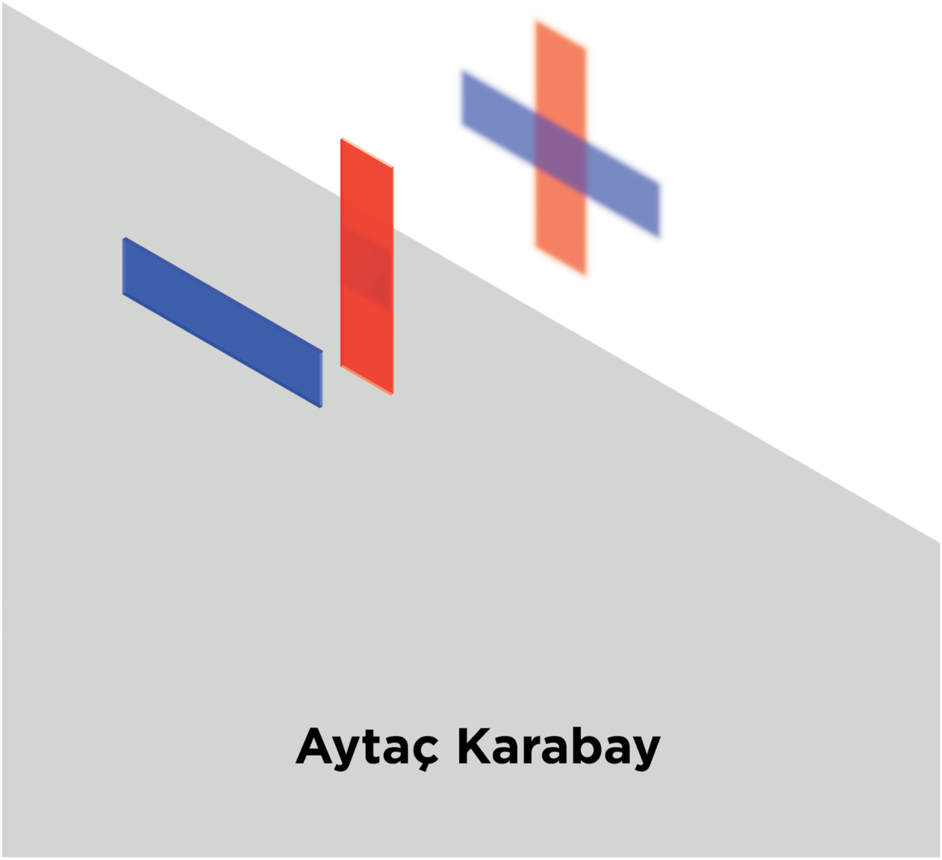
From stimulus to representation

Target identification in rapid serial visual presentation



Aytaç Karabay

Cover & layout design by Aytaç Karabay & Lokman Önsoy
Printed by Off Page (offpage.nl)

ISBN: 978-94-034-2859-8 (paperback)
ISBN: 978-94-034-2860-4 (eBook)

university of groningen

From Stimulus to Representation: Target Identification in Rapid Serial Visual Presentation

PhD thesis

to obtain the degree of PhD at the
University of Groningen
on the authority of the
Rector Magnificus Prof. C. Wijmenga
and in accordance with
the decision by the College of Deans.
This thesis will be defended in public on
Thursday 3 September 2020 at 12.45 hours

by

Aytaç Karabay

born on 25 May 1989
in Hekimhan, Turkije

Supervisor

Prof. E.G. Akyürek

Prof. M. M. Lorist

Assessment Committee

Prof. H. Bowman

Prof. H. Slagter

Prof. H. van Rijn

Table of Contents

Chapter 1

General Introduction

In this chapter, definitions of the key phenomena of interest in this dissertation are provided, and placed within a theoretical context. First, the attentional blink is introduced, and relevant theories of the attentional blink are briefly explained. Second, the related phenomenon of lag-1 sparing is discussed, and possible ways to account for sparing within the context of attentional blink theories are detailed, as well as an alternative account that is based on the idea that successive targets in rapid serial visual presentation may become temporally integrated. Because it is central to the present thesis, the concept of temporal integration is subsequently explained in some detail. Finally, the empirical work of this dissertation is introduced, with reference to the current research questions.

1.1. The Attentional Blink

The visual environment around us changes constantly in both space and time. Attention is a powerful cognitive function that enables us to select and attend to relevant bits of information over irrelevant ones. But our attentional system is not unconstrained. The attentional blink is a phenomenon that highlights the limits of dynamic attentional selection, that is, selection in time. The attentional blink is the marked difficulty that occurs when trying to identify a target stimulus when it follows another relevant stimulus within a relatively short interval of approximately 200 to 500 ms (Broadbent & Broadbent, 1987; Raymond, Shapiro & Arnell, 1992). In the last 25 years, the attentional blink has proven to be one of the most robust cognitive phenomena, occurring in diverse experimental paradigms, with countless replications reported worldwide.

The attentional blink is most often studied by means of the so-called rapid serial visual presentation paradigm (RSVP). In a classic RSVP paradigm, which consists of target and distractor items, a series of visual stimuli are sequentially shown at the same spatial location at a rate of around ~10 items per second. In an RSVP, the target items are to be detected and often identified and reported among distractor items. When there is only one target item in an RSVP, identification accuracy of the target is quite high, around 85% or more (Raymond, Shapiro & Arnell, 1992). However, when a second target (T2) is added to the stream, the identification accuracy of the T2 might suffer (Figure 1.1), which demonstrates that, dependent on lag, it is the (attentional) selection of T1 or T1 consolidation in working memory that causes the deficit. Interestingly, when targets follow each other in direct succession (Lag 1), the identification performance of the second target is high; this phenomenon is known as lag-1 sparing.

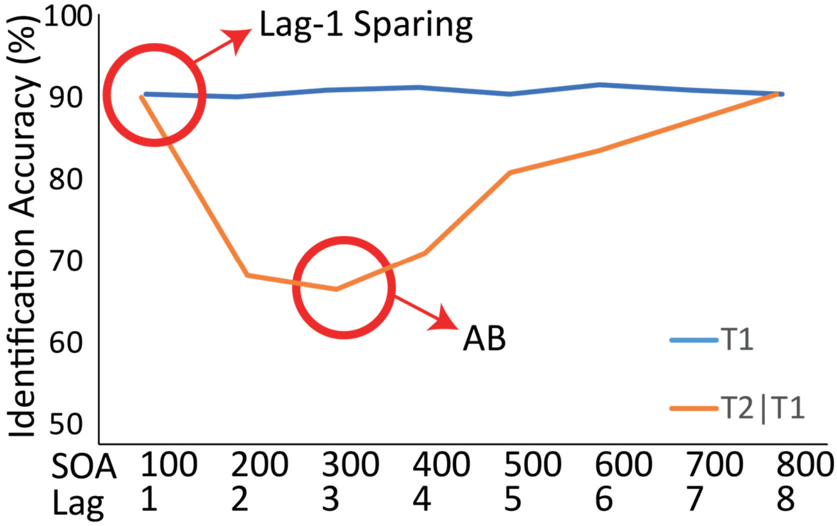


Fig. 1.1. An illustration of the attentional blink and lag-1 sparing. The plot is created from fictitious data. The horizontal axis shows temporal target locations relative to the first target (T1), i.e., at lag 1, T2 follows T1 in direct succession, and at lag 3, there are two distractors in between T1 and T2. SOA indicates the stimulus onset asynchrony in milliseconds. The vertical axis shows identification accuracy in percent correct. T2|T1 means the accuracy of T2 identification in the trials in which T1 was identified correctly.

1. 2. Theories of the Attentional Blink

There are different theories that explain the attentional blink (for a review see Dux & Marois, 2009). Raymond, Shapiro & Arnell (1992), who proposed the term attentional blink (AB), explained the AB in a way that the distractor following T1 interferes with the processing of T2. Before the processing of T1 ends, an attentional suppression, which lasts a couple of hundred milliseconds, occurs to complete the processing of T1. Because of the attentional suppression, an attentional gate closes, which inhibits the processing of T2, to protect that of T1. As a result, the encoding of the identity of T2 suffers. More recent theories explain the AB similarly; as a result of the capacity limitations of temporal attention, and/or as a consequence of attentional suppression due to the distractor following T1. Even though there are numerous theories of the AB, we will focus on the '(episodic)-simultaneous type/serial token ([e]STST) model', on the one side, and the 'boost and bounce model' on the other side (Chun & Potter, 1995; Bowman & Wyble, 2007; Wyble, Bowman & Nieuwenstein, 2009; Olivers & Meeter, 2008). The main difference between these models is that the boost and bounce theory accounts for T2 identification deficits through an attentional suppression effect that arises to prevent distractors following T1 to enter working memory, while the two-stage model and the (e)STST model claim that T2 cannot be encoded before the encoding phase of T1 ends.

1.2.1. The (Episodic)-Simultaneous Type/Serial Token Model

The e-STST model is based on the two-stage model (Chun, & Potter, 1995) and the idea of types/tokens (Kanwisher, 1987). The two-stage model suggests that the AB occurs due to capacity limits. As its name implies, the model consists of two stages. In the first stage, each incoming visual stimulus is processed and the relevant target features are analyzed. The first stage does not involve consolidation of the target stimuli so that a second stage is needed where the target identity is consolidated in working memory in order to report the targets correctly. In the second stage, momentarily active targets are transferred to more durable representations. However, the second stage is capacity limited, unlike the first stage. After T1 is analyzed in the first stage, since it matches the relevant target features such as color, luminance, category, the second stage processing of T1 starts. As mentioned above, T1 is consolidated in working memory in the second stage. Although items following T1, including T2, are analyzed in the first stage regardless of the processing stage of T1, before the second stage of T1 processing ends, the processing of T2 in the second stage cannot start in parallel. In other words, the delay originates from access to the second stage. Hence, the longer processing of T1 in the second stage continues (e.g., if it is more complex), the higher the chance that T2 identity will be lost, because it will eventually perish in the first stage before it can be consolidated (Chun & Potter, 1995).

In STST, these processing stages are associated with the processing of so-called types and tokens. Types are generic representations of stimuli. Types are active only during the encoding and retrieval phases of information processing, hence types are not stored in memory. Tokens are episodic instantiations of stimuli (Kanwisher, 1987). In a typical RSVP task, the target set or template consists of types. For example, when target items are numbers and distractor items are letters, target types are numbers. When an actual stimulus in the stream matches the target type, then it is bound to an episodic token, reflecting its temporal context. At the end of the stream where target items are to be reported, tokens reactivate the type node. The tokenization process is related to the temporal order of the targets, meaning that the perceived order of the targets depends on which target is bound to which token. According to this model, T2 can only be bound to a token after T1 is already encoded (Bowman & Wyble, 2007). Hence, this model predicts that the AB occurs because of the tokenization period of T1, during which T2 cannot undergo the same process, which is in essence similar to the two-stage model.

In comparison to the original STST model, the eSTST tokenization process changed slightly to better account for the phenomenon of extended sparing, which will be further detailed below. In brief, the original STST model allowed successive targets to be bound 'accidentally' to the same token, accounting for order report errors and identity sparing at lag 1. By contrast, tokenization in eSTST is strictly serial and report order errors are attributed to faster tokenization of the second target under certain conditions (Wyble, Bowman & Nieuwenstein, 2009).

1.2.2. Boost and Bounce Model

In a way, the boost and bounce model is a modern extensive version of the inhibition model (Raymond, Shapiro & Arnell, 1992). According to the inhibition model, the post-T1 stimulus (i.e., a distractor) is inhibited by a suppressive mechanism in order to reduce confusion between targets and distractors. When the second target's temporal onset is close to the first one, the identification of the second target is limited due to the attentional suppression that is in effect to suppress a post-T1 stimulus. Similarly, the boost and bounce model (Olivers & Meeter, 2008) rejects the idea that capacity limits induce the AB. Instead, the theory suggests the following mechanism: When a target matches with the target template (target set), attention is boosted. However, after this attentional boost, when the first successive distractor appears on the screen, an ensuing suppression of information processing of that distractor causes the AB.

More specifically, boost and bounce theory states that a representation of the target set is stored in the working memory. The representation in working memory serves to select the target items over the distractor items in a stream. When a target item matches with the representation of a target set the attentional boost occurs. Somewhat paradoxically, the distractor item that follows the T1 (T1+1) also benefits from that attentional excitation and enters working memory. But then, since the distractor item does not match with the target set, and it should have been ignored, a transient, strong suppression response occurs, the bounce. Because of this suppression of the T1+1 distractor, information processing of the subsequent items, including T2 at short lag, suffers as well.

1.3. Lag-1 Sparing

As alluded to above, the attentional blink does not always occur. When T2 follows T1 immediately (lag 1), identification accuracy is often almost as good as that of T1, which is known as lag-1 sparing. However, an increased number of order reversals is also observed when targets follow each other in direct succession in RSVP (Chun

& Potter, 1995; Hommel & Akyürek, 2005; Wyble, Bowman, & Nieuwenstein, 2009). In other words, at lag 1, T2 identification accuracy is quite high, but the probability that T1 is reported as T2 and vice versa is higher than usual. Lag-1 sparing constitutes a remarkable exception to the intuitive rule of thumb that when targets are in close temporal proximity, performance (on the second one) should be impaired. It is therefore important for any comprehensive theory of temporal attention, to be able to account for not only the attentional blink, but also for sparing.

1.3.1. Lag-1 Sparing in the (e)-STST Model

The e-STST model predicts that an attentional blaster boosts the processing of T1. At lag 1, where T2 follows T1 in direct succession, T2 also benefits from the attentional blaster caused by T1, again due to a certain sloth in the system, so that T2 tokenization is facilitated. Thereby, this model also predicts that order reversals of targets are more frequent at lag 1 with less identification accuracy of T1 (Wyble, Bowman & Nieuwenstein, 2009). More specifically, T1 and T2 compete in the model, such that tokenization of T2 interferes with T1, reducing the identification success of the latter, and increasing the time needed to consolidate it.

In STST, lag-1 sparing comes with two costs. (I) T1 accuracy is lower because of competition between targets at lag-1 in the tokenization process, which results in benefits on T2 identification, and costs on T1 identification. (II) Target swap errors are more pronounced at lag-1. According to the model, transient attentional enhancement occurs when T1 is detected. If T2 then advances to the second stage at Lag-1, T2 benefits from that attentional enhancement and both T1 and T2 become active. Since both targets are active, they bound to the same token, causing temporal order errors (swaps). This loss of temporal information is a characteristic of the failure of the tokenization process (Bowman & Wyble, 2007). In e-STST, a different mechanism is implemented; when T2 tokenization proceeds relatively unimpaired, and then finalizes before T1, temporal information of targets gets mixed, because T2 gets bound the first available token and T1 to the second.

1.3.2. Lag-1 Sparing in the Boost and Bounce Model

Similar to the e-STST model, the boost and bounce model explains sparing through the benefits gained by T2 from the attentional excitation caused by T1. The boost of T2 results in higher identification accuracy, while T1 identification accuracy is lower when targets follow each other successively (Olivers & Meeter, 2008). The tendency to report T2 as if it were the first target can then be attributed to a prior entry effect, in which the stronger target (in this case T2, which received the boost) appears to have come first (cf. Hilkenmeier, Olivers, & Scharlau, 2012).

1.3.3. The Temporal Integration Account

An alternative, more AB theory-agnostic account of lag 1 performance was proposed by Hommel and Akyürek (2005), coining the idea that T1 and T2 may get integrated together by falling in the same perceptual episode due to their temporal proximity. This was thought to be reflected by the increased number of order reversals at lag 1, which indicates a loss of temporal information about the individual targets. Hence, if two of the targets in an RSVP stream are visually compatible, they may be perceived as one. The idea of temporal integration is, thus, to be investigated to understand lag 1. Perceptual target integrations in an RSVP is possible since the total duration of succeeding targets do not exceed 200 ms, which is somewhat of an upper limit to integrate visual information in basic missing element tasks (Hogben & Di Lollo, 1974; Di Lollo, 1980). Because of the importance of the concept of temporal integration for this thesis, it will be discussed in some detail in the following section.

1.4. Temporal Integration

In general, to make a meaningful representation of the visual environment, the integration of certain elements within the visual environment is necessary. Across time also, we do not perceive our visual environment as snapshots, instead, these snapshots are integrated into a fluent motion. For instance, when a car moves on a high way, we do not perceive each location of the car discretely, instead, a moving car from one direction to another is perceived. This is achieved by temporal integration, which is a perceptual process combining ongoing stimuli up to 200 ms (Hogben & Di Lollo, 1974; Di Lollo, 1980).

Temporal integration is often studied with missing element tasks (MET). In a classical MET, there is a 5 by 5 dot/square grid. There are two displays, which are shown successively, each one contains 12 dots/squares leaving only one location on the grid, and the task is to find the missing location on the grid (Di Lollo, Arnett & Kruk, 1982). Two displays have to be integrated in order to find the missing element on the grid (Di Lollo, Arnett & Kruk, 1982). Several factors, such as age, stimuli saliency, display duration, inter-stimulus interval duration influence performance in MET (Di Lollo, 1980; Kinnucan & Friden, 1981; Saija et al., 2017; Akyürek & de Jong, 2017). Although there are a substantial number of studies on temporal integration with the MET, perceptual integrations between competing stimuli in ongoing RSVP streams have not been studied extensively.

1.4.1. Temporal Integration in RSVP

There has been a select number of studies on the properties of temporal integration in the context of RSVP, which will be briefly reviewed here. RSVP presents a somewhat special case with regard to integration, firstly because it involves temporal intervals that are substantially longer than typically tested in missing element tasks, and secondly because it provides an opportunity to examine potentially shared underlying mechanisms of temporal attention and temporal integration.

The idea that targets fall in the same perceptual/attentional episode in an RSVP task was first supported by findings of Hommel and Akyürek in 2005, as mentioned above. They stressed the fact that even though target identification is high at lag 1 (when targets follow each other without distractors in between), order reversals of targets (when the first target is reported as the second and vice versa) were high as well, suggesting a loss of target-specific temporal information. This finding prompted the idea that these two targets may have fallen in the same episode. A series of papers followed in which measures of order errors were exploited to investigate the properties of temporal integration in RSVP (Akyürek & Hommel, 2005; Akyürek, Riddell, Toffanin, & Hommel, 2007; Akyürek, Toffanin, & Hommel, 2008).

Indeed, until the study published by Akyürek et al. (2012), temporal integration in RSVP was inferred exclusively from the frequency of order errors, as an indirect measure of temporal confusion. Akyürek et al. (2012) introduced a modified RSVP task in which target identities were visually compatible, such that when two targets were overlaid, the composite figure was also a valid target identity. Thus, one target identity could be "/", and the second "\", and their combined (integrated) appearance would be "X", which was also a valid single-target identity. If successive targets are indeed temporally integrated, this design would thus enable the participants to report that single illusory, integrated target, which was indeed observed.

Akyürek et al. (2012) proceeded to investigate whether allowing temporal integration at lag 1 would correspond to the typical percentage of order reversals observed in classic designs. They tested the question with four experiments and showed that the frequency of order reversals corresponded closely with the frequency of target integration. Furthermore, they found that lag influenced temporal integration as expected, with integration occurring for successive, but not temporally further separated targets: A much higher percentage of temporal integration reports was observed at lag 1, compared to lag 3 and lag 8. This study was thus the first direct evidence showing that targets in an RSVP stream fall in the same perceptual episode.

1.4.2. Cognitive Consequences of Temporal Integration in RSVP

One might wonder why temporal target integration occurs at all in RSVP. Is it a consequence of our perceptual system being outpaced? Or is integration due to an optimization strategy to balance speed with information processing capacity? Evidence suggests that it is the latter. Wolff et al. (2015) investigated pupil dilation in a hybrid integration-AB task in order to characterize the mental effort needed to process targets. There was a clear difference in pupil size between conditions in which one target was perceived (i.e., one target trials correct response, only T1 reported correctly, and also temporal integrations) and when two of the targets (i.e., order reversals and T1 and T2 fully correct) were processed separately. The results, thus, showed that the mental effort required to process two targets as a single integrated percept was lower than two targets processed separately. Also, the mental effort observed in the single-target condition, and in the temporal integration condition were almost identical. Therefore, it could be argued that processing targets as integrated percept saves energy, as is reflected by mental effort measured by pupil size.

In a second study, Akyürek et al. (2017) investigated differences in working memory load between trials in which one target was reported, compared to integrated reports of the targets, and two targets correct reports. They compared Contralateral Delay Activity (CDA) as a measure of working memory load (Vogel & Machizawa, 2004; Perez & Vogel, 2012) between conditions. According to their findings, CDA levels did not differ between conditions in the early window (200 to 600 ms). However, there was a significant difference in single and integrated trials compared to two target reported trials in the late window (600-1000 ms). The results indicated less working memory load in single and integrated trials compared to dual-target trials. Furthermore, CDA did not differ between single target, and integrated targets reported trials, providing clear evidence that integrated target representations are efficient in that they take up less space in working memory.

If integration in RSVP is efficient, it might be expected that the subjective experience also improves. Simione et al. (2017) added a Perceptual Awareness Scale (PAS) to a hybrid RSVP task, to investigate whether integration reports are associated with increased perceptual uncertainty. After each response prompt, participants were asked to rate their perceptual experience of the stimuli that they reported, on the PAS scale ranging from no experience (mere guess) to clear experience. Interestingly, their results suggested that when participants integrate the succeeding target stimuli, the average PAS score was even greater than when both targets were identified correctly, meaning that the perceptual experience of the integrated percept of targets was more clear than when both targets identified correctly at Lag 1. On the other side, the perceptual experience of (remaining, actual) order reversals was as poor as the condition in which both targets were misreported. This study shows clear dissociation between order reversals and temporal integration in terms of perceptual experience, and a clear association between temporal integration and fully successful identification in terms of having a clear perceptual experience. There was thus also no evidence to suggest that integration reports are borne out of perceptual uncertainty.

1.5. The Present Study

In view of the findings to date, temporal integration seems like a plausible process to contribute to the perception of successive targets in RSVP. However, a major question that remains largely unanswered so far is how two competing targets actually end up falling into the same perceptual episode. It seems likely that both exogenous (i.e., stimulus-related) and endogenous factors could play a role. The purpose of this dissertation is to investigate the similarities and dissimilarities of underlying cognitive mechanisms between temporal target identification and integration from low-level stimuli features to endogenous factors.

Starting with the former, the basic features of target stimuli is likely influential on temporal target processing. Attentional performance has been shown to change as a function of target contrast (Chua, 2005), the presence of distractors between targets (Brisson, Spalek, & Di Lollo, 2011; Nieuwenstein, Potter, & Theeuwes, 2009), the similarity of targets (Sy & Giesbrecht, 2009), and target-distractor similarity (Duncan & Humphreys, 1989; Müsch, Engel & Schneider, 2012). In the context of RSVP, for instance, the color similarity between targets has clear effects. Akyürek, Köhne, and Schubö (2013) showed that when target colors are the same compared to the target of different colors, T2 identification was less accurate due to increased interference between the targets, as a result of feature overlap. Again, however, it is currently not clear how such stimulus similarity influences temporal integration. We thus put this to the test in chapter 2.

Next to these basic features of the target stimuli, the appearance of the target stimuli could clearly affect the likelihood of integration, if only because targets are shown on the same spatial location in RSVP tasks. If the targets are not sufficiently compatible, instead of integration, backward/forward masking of targets may occur (Enns & Di Lollo, 2000). By contrast, if targets form a good figure together, integrated target percepts may be facilitated. Good figures are modulated by Gestalt laws, which have a strong influence on visual perception (Wertheimer, 1938; for review, Wagemans et al., 2012). Indeed, in related paradigms, it has been shown that these Gestalt figures (such as illusory Kanizsa contours) not only influence spatial attention and perception (for review, Wagemans et al., 2012), but also temporal attention (Kellie & Shapiro, 2004; Conci & Müller, 2009). However, to what extent good figures modulate the integration of competing for target stimuli in RSVP is yet unclear. We thus tested how Kanizsa contours might influence temporal attention and integration in chapter 3.

As mentioned previously, endogenous factors might also influence dual-target RSVP task performance, including aspects such as personality (MacLean & Arnell, 2010), training, etc. (Garner, Tombu & Dux, 2014), as well as the physiological state of the observer. For example, it has been shown that levels of gamma-aminobutyric acid (GABA), which is an inhibitory neurotransmitter, influence visual attention (Paine, Slipp & Carlezon, 2011). In RSVP, Leonte et al. (2018) investigated the effects of acute GABA supplementation on temporal attention, temporal integration and spatial attention in a randomized, double-blind, placebo-controlled design. They found significant improvements after acute supplementation of GABA on temporal attention (T2|T1 accuracy) but not on temporal integration and spatial attention.

Similar to GABA, flavanols, which are found in dietary sources, influence the brain. Flavanols activate nitric oxide synthesis, which increases vasodilation including brain arteries (Francis et al., 2006). As a result, blood flows faster in the brain after two hours of flavanols consumption. In addition, increased arterial spin labeling perfusion in the anterior cingulate cortex and central opercular cortex of the left parietal lobe was observed after 2 hours of flavanols consumption (Lamport et al., 2014). It is known that anterior cingulate cortex is responsible for modulation of attention and executive functions, which are highly related to temporal target processing in RSVP (Bush et al., 2000; Marois et al. 2000). Furthermore, we wanted to test if the acute effects of cocoa flavanols on temporal attention are coherent between different attentional mechanisms. In order to do that, we used a pop-out visual search task next to the dual-target RSVP task and investigated if cocoa flavanols influence temporal and spatial attention in a similar direction. Hence, we aimed to test if flavanols have an effect on dual-target processing in RSVP, and target detection in visual search tasks in chapter 4.

General outcomes are discussed with regard to the question of this dissertation in chapter 5. Furthermore, existing theories about AB is evaluated with the findings of this dissertation and directions for future research are given in chapter 5.

Chapter 2

Temporal integration and attentional selection of color and contrast target pairs in rapid serial visual presentation

This chapter was previously published as:

Karabay, A., & Akyürek, E. G. (2019). Temporal integration and attentional selection of color and contrast target pairs in rapid serial visual presentation. *Acta Psychologica, 196,* 56–69. doi:10.1016/j.actpsy.2019.04.002

Data and code available at osf.io/rwkx8

2.1. Abstract

Performance in a dual target rapid serial visual presentation task was investigated, dependent on whether the color or the contrast of the targets was the same or different. Both identification accuracy on the second target, as a measure of temporal attention, and the frequency of temporal integration were measured. When targets had a different color (red or blue), overall identification accuracy of the second target and identification accuracy of the second target at Lag 1 were both higher than when targets had the same color. At the same time, increased temporal integration of the targets at Lag 1 was observed in the different color condition, even though actual (non-integrated) single targets never consisted of multiple colors. When the color pairs were made more similar, so that they all fell within the range of a single nominal hue (blue), these effects were not observed. Different findings were obtained when contrast was manipulated. Identification accuracy of the second target was higher in the same contrast condition than in the different contrast condition. Higher identification accuracy of both targets was furthermore observed when they were presented with high contrast, while target contrast did not influence temporal integration at all. Temporal attention and integration were thus influenced differently by target contrast pairing than by (categorical) color pairing. Categorically different color pairs, or more generally, categorical feature pairs, may thus afford a reduction in temporal competition between successive targets that eventually enhances attention and integration.

Keywords: integration; attentional blink; stimulus features; color; contrast; rapid serial visual presentation.

2.2. Introduction

We live in a dynamic environment, in which we are continuously exposed to changes over time. Attention is a powerful cognitive mechanism that helps us to process incoming sensory information, by selecting relevant items and events over irrelevant ones, both in time and space. It has been hypothesized that attention is also required to integrate raw, featural information into coherent representations (Treisman & Gelade, 1980). Thus, the perception of a certain red-green color and roundish shape at a particular location in the visual field may be attentionally forged into that of an apple. Such attentional processing is necessarily limited, and when it comes to shifting attention from one object to another in a very short time interval (200-500 ms), our ability to identify that second object is further constrained. This has been termed the attentional blink (AB), which is a phenomenon that arises due to temporal limitations of attention (Raymond, Shapiro, & Arnell, 1992), and which has been taken to reflect the speed at which feature integration (episodic "tokenization") can occur (Treisman & Kanwisher, 1998).

In the laboratory, rapid serial visual presentation (RSVP) is a commonly used technique to study temporal attention. A classical RSVP task consists of a stream of stimuli comprising two targets (labeled T1 and T2) to be attended, and multiple distractors to be ignored, where the stimuli follow each other at a pace of about 10 items per second in the center of the screen, so that the items mask each other. The ability of the observers to detect and identify the second target (T2) in RSVP then depends on various factors that affect attentional efficiency (for a review, see Dux & Marois, 2009). These include endogenous factors, such as pre-stimulus neural activity and rhythmic brain activity (Ranconi, Pincham, Cristoforetti & Szűcs, 2016; Ranconi, Pincham, Szűcs & Facoetti, 2016), as well as exogenous ones, such as the temporal delay or lag between targets (Broadbent & Broadbent, 1987; Raymond et al., 1992), the presence of distractors after T1 (Brisson, Spalek, & Di Lollo, 2011; Nieuwenstein, Potter, & Theeuwes, 2009), and the similarity of targets with other targets and with distractors (Duncan & Humphreys, 1989; Sy & Giesbrecht, 2009).

To account for such factors, several models of the AB have been developed (e.g., Olivers & Meeter, 2008; Taatgen, Juvina, Schipper, Borst, & Martens, 2009; Wyble, Bowman, & Nieuwenstein, 2009). Following accounts of spatial attention (e.g., Wolfe, 1994), the processing and integration of stimulus features have been incorporated as a central mechanism in an influential model of the AB, the (e-)STST model of Wyble and colleagues (Bowman & Wyble, 2007; Wyble, Bowman & Nieuwenstein 2009). The model suggests that items in an RSVP that match with the target template induce attentional excitation. Specifically, when an item's type, that is, its featural representation, matches with the target template, the type is bound to a token, which instantiates an episodic representation of the target stimulus in working memory. Further attentional activation is suppressed during this stage of episodic registration until T1 is linked to a specific token and maintained in working memory. This temporary suppression elicited by T1 induces the AB, as it keeps the subsequent T2 type from binding to a token in turn. The tokenization process in this model might be understood as a form of temporal feature integration, binding (a set of) features to temporal coordinates.

Temporal integration processes have also been proposed to play a crucial role when targets follow each other in direct succession in RSVP (Akyürek et al., 2012; Akyürek, Riddell, Toffanin, & Hommel, 2007; Akyürek & Wolff, 2016; Hommel & Akyürek, 2005). In dual target RSVP, the condition in which T2 directly succeeds T1 without intervening distractors is called Lag 1. Lag 1 often produces unusual performance; instead of resulting in very low performance on T2, which might be expected in view of the very limited amount of time available to process both targets, identification accuracy of T2 can be quite high, which is known as lag-1 sparing (for a review, see Visser et al., 1999). It has also been observed that lag-1 sparing is often accompanied with a loss of temporal order information of targets, which causes report order errors, where T2 is reported as T1 and vice versa (Hommel & Akyürek, 2005; Potter, Staub, & O'Connor, 2002). This finding has prompted the idea that the targets may have been integrated together into the same perceptual episode (Hommel & Akyürek, 2005). This was later confirmed by using a modified task in which both individual targets (e.g., "\" or "/") as well as integrated targets were valid target identities (e.g., "X") and could thus be reported directly (Akyürek et al., 2012).

If (feature) integration indeed underlies performance in RSVP tasks as described above, then the ease or speed of integration itself should have a modulatory role therein. To our knowledge, this has not been directly investigated to date. However, previous related research has shown that identifying a target in an RSVP stream becomes easier when targets and distractors differ more from each other (Chun & Potter, 1995; Maki, Bussard, Lopez, & Digby, 2003). Differences between T1 and T2 have also been found to modulate performance, implicating temporal integration. Hommel & Akyürek (2005) as well as Chua (2005) observed an increase in target report order errors for targets presented at Lag 1 that had similar contrast. To account for this finding, Hommel & Akyürek proposed that integration and competition may both play a role in the processing of successive targets. When one target is more strongly represented (due to its higher contrast, for instance), it wins out over the other target and is thereby more likely to be reported. However, when both targets are of similar representational strength (e.g., having similar contrasts), they may both persist and together become part of an integrated representation. It must be noted here that order errors in classic RSVP tasks remain an indirect measure of integration and may also be mediated by attentional factors.

The question furthermore remains whether these interactions at Lag 1 are generically related to stimulus strength and/or similarity, such as results from manipulating stimulus contrast. It seems plausible that integration might be driven also by feature-specific differences. One study by Akyürek, Schubö, and Hommel (2013) manipulated featural target similarity (color) in a lateralized RSVP design, hypothesizing that for the identification of two successive targets of the same category (e.g., both letters), feature overlap may cause interference by making it harder to distinguish the targets. For targets of the same color, interference was indeed observed at Lag 1, but this effect must be interpreted in the context of their task, in which T1 and T2 were spatially separated, thus precluding straightforward integration and presumably any benefits that might thereby be obtained. A direct, non-spatial test of the consequences of featural similarity between targets for temporal integration and attention is thus still lacking. The purpose of the present study was to perform this test and to compare the outcomes with a non-featural target difference.

2.2.1. The Present Study

We aimed to investigate how differences in color or contrast of T1 and T2 would influence target identification accuracy and temporal integration in RSVP. In doing so, target templates were held constant for different colors and contrasts, to ensure that targets could not be found on the basis of any unique (specific) color or contrast, and so that these features were truly irrelevant for the identification task. Featural task relevance has been shown to interact with performance in RSVP tasks (Akyürek, Köhne, & Schubö, 2013), which for the present purpose would have made it harder to isolate cause and effect of feature similarity between targets. We adopted the task developed by Akyürek et al. (2012) for this purpose in a way that target color and contrast either matched or did not. As a measure of temporal attention, we first investigated whether targets of different color or contrast resulted in comparable modulations of T2 identification accuracy compared to same-color/contrast pairs. We secondly investigated whether these color/contrast pairs also affected temporal target integration.

2.3. Experiment 1A

Experiment 1A was conducted to test the effects of manipulating the color match between the targets on temporal integration and attention. We hypothesized that T2|T1 accuracy at short lag when T1 and T2 color did not match would be higher than when T1 and T2 color matched, due to decreased episodic distinctiveness and increased masking in the latter case. In terms of temporal integration at Lag 1, two scenarios may be conceivable. On the one hand, increased featural overlap between same color target pairs may increase mutual competition and consequently induce a stronger segregation response between targets in order to keep them apart episodically (cf. Akyürek, Schubö, & Hommel, 2013). Therefore, integration between targets might occur less frequently in the same color condition. On the other hand, if feature similarity actually diminishes the competition between targets (cf. Hommel & Akyürek, 2005), those same-color target pairs may rather increase temporal integration.

2.3.1. Method

2.3.1.1. Participants

For each experiment, 24 was set as the a priori minimum required number of participants; and to meet this number (even after possible exclusions), 30 participants were invited through the departmental subject pool. Consequently, 25 healthy students (17 female) of the University of Groningen participated in the study in exchange for course credits (mean age = 20.3 years, range = 17-31). All participants reported normal/corrected-to-normal visual acuity and none of them reported colorblindness. The study was conducted in accordance with the Declaration of Helsinki (2008) and approved by the ethical committee of the Psychology Department of the University of Groningen (approval number: 15044-NE). Written informed consent was obtained prior to participation.

2.3.1.2. Apparatus and Stimuli

Participants were seated in dimly lit, sound attenuated testing cabins. The distance between participants and the monitor was not fixed, but it was approximately 60 cm. Stimuli were presented on a 22" CRT monitor (Iiyama MA203DT). The resolution of the monitor was set to 1024 x 768 pixels, at 16-bit color depth, and the refresh rate was set at a frequency of 100 Hz. Stimulus presentations, trial events and data collection were controlled by E-prime 2.0 Professional (Psychology Software Tools) under the Windows 7 operating system. Responses were collected by a standard labeled keyboard.

Stimuli were presented on a light gray background (RGB 192,192,192; 207 cd/m2). Distractor stimuli were chosen from the full Latin alphabet, excluding O and X, without replacement on each trial. Distractor stimuli were presented in black (7 cd/m2) 52 pt, Courier New Font. The fixation cross (+) was presented in the same color and font (18pt) on each trial. All target stimuli were presented within a square area of 60 by 60 pixels (2.22° by 2.22° of visual angle) in the center of the screen. As shown in the Figure 2.1, target stimuli were isoluminant, monochromatic figures in either red (RGB 185, 0, 0; 45 cd/m2) or blue (RGB 0, 0, 255; 46 cd/m2).

2.3.1.3. Procedure

There were two blocks in the experiment, and 208 experimental trials in each block. Participants were offered to have a break between two blocks. In one of the blocks, T1 and T2 had the same color (T1 red and T2 red, or T1 blue and T2 blue). In the other block, T1 and T2 had different colors (red-blue, or blue-red). The order of the two blocks (i.e., the same and different color conditions) was counterbalanced between participants. The experiment started with 22 practice trials. These trials were omitted from analyses. The duration of the experiment was approximately 45 minutes.

Participants started the experiment by pressing Enter. After 100 ms of pressing Enter, a fixation cross showed up on the screen for 200 ms. The ensuing RSVP consisted of 18 stimuli of 70 ms each, separated by 10 ms inter-stimulus interval. The first target appeared in the fifth or seventh position within the RSVP, which was random but equally distributed. The second target similarly followed the first target either as the first item (Lag 1), as the third item (Lag 3), or as the eighth item (Lag 8). There was only one target in 7.7% of the trials. In total, 46.2% of all targets were presented at Lag 1 so as to obtain a reliable estimate of temporal integration frequency, and 23.1% of targets were presented at Lag 3 and at Lag 8. There was a 100 ms blank after the RSVP, followed by two successive response prompts asking the participants to enter T1 and T2 in the correct order. Participants were able to enter two targets by pressing the related labeled key (2, 4, 5, 6, 7, 8, or 9) on the numeric keypad. Moreover, participants could enter just one target by pressing the related button at the first or second response prompt, and skipping the other prompt by pressing Enter.

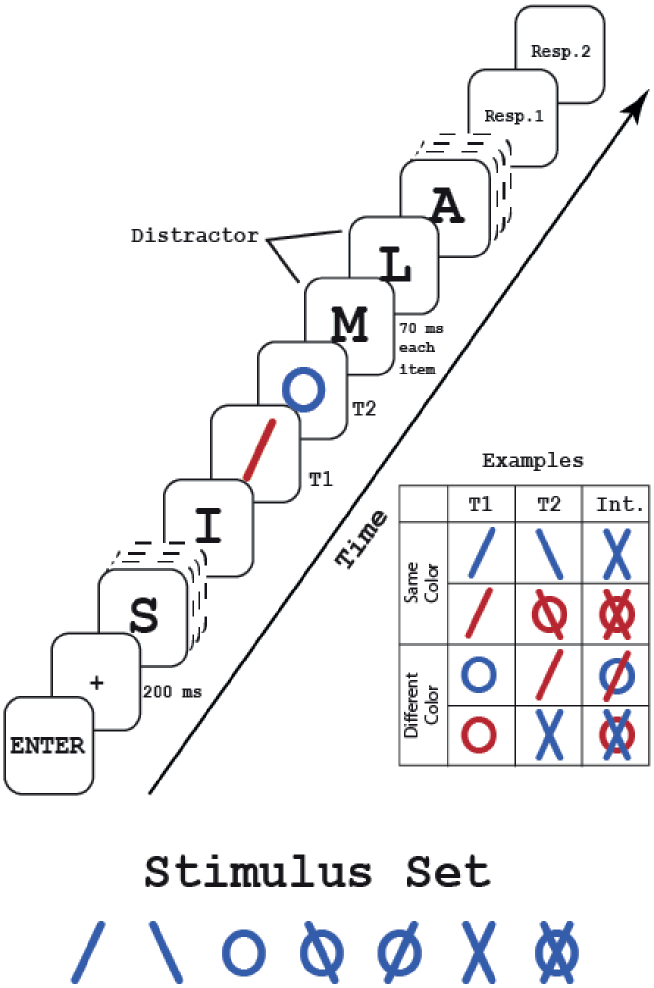


Fig. 2.1. Illustration of the hybrid rapid serial visual presentation task at Lag 1 where targets follow each other successively. T1 and T2 indicate the first and second target. Letters are distractors, and targets appear among these in the stimulus stream. There was a 10-ms blank interval between stimuli. Resp. refers to the response prompt. Example target stimuli are shown in the right bottom corner of the figure. Int. means temporal integration of targets, which is a unified perception of the targets. Note that stimuli consisting of multiple colors were never shown as targets, but could nonetheless be reported as integrated (configurally). At the bottom of the figure, the full stimulus set of the experiment is shown. The actual RGB values of the stimuli varied depending on experimental conditions.

2.3.1.4. Design and Analysis

T1 and T2 accuracies were measured as the correct identification of targets at the correct response prompts (i.e., order-sensitive). T2 accuracy was measured on the condition that T1 was identified correctly (i.e., T2|T1). The exact combination of T1 and T2, indicated at one of the response prompts, without another response given at the other response prompt, was defined as temporal integration. When T1 was reported as T2 and vice versa, this was defined as an order reversal. Only Lag 1 was included in the analyses for temporal integration and order reversals, since neither temporal integration nor order errors were expected to occur in a substantial number of trials at Lag 3 and 8.

Separate repeated measures analyses of variance were run for T1 accuracy, T2|T1 accuracy and paired sample t-tests were used to analyze temporal integration and order reversals. Greenhouse-Geisser corrected p values were reported when necessary. A 2 (Color: same/different) by 3 (T2 Lag: 1, 3, 8) design was used in the repeated measures analysis for T1 and T2|T1 accuracies. Tukey HSD scores were computed in order to further characterize interaction effects. Partial eta squared ($\eta 2p$) as a measure of effect size was calculated for T1 and T2|T1 accuracies, and Cohen's d was calculated for temporal integration and order reversals in order to characterize the effect size.

A second set of 2 by 2 by 3 analyses was carried out, in which T1 color (blue, red), T2 color (blue, red) and lag were used as independent variables in the model. Although we did not have color-specific hypotheses, these more detailed analyses provide a view on the effects of specific target color pairs, and we, therefore, included them in the Appendix.

Apart from the visualizations of the data as analyzed, additional compound scores for T2 identification were also added to the relevant figures (grey lines). These scores serve to provide a view on target identification performance without taking order into account, as commonly done in RSVP studies. To this end, all trials were selected in which T1 was identified correctly as either the first target, as the second target, or as part of an integrated report. Order-insensitive T2 accuracy, again including order reversals and integrations, was then plotted as a percentage of those trials.

2.3.1.5. Data Availability

In order to provide scientific transparency, we uploaded the data to the Open Science Framework with the identifier rwkx8 (osf.io/rwkx8), where they are publicly available.

2.3.2. Results

T1 Accuracy: Overall accuracy in one-target trials was 89.9%, and overall T1 accuracy in two-target trials was 66.7%. Lag and Color had significant main effects on T1 accuracy, F(1, 32) = 165.99, MSE = .03, p < .001, η2p = .87; F(1, 24) = 4.96, MSE = .01, p < .05, η2p = .17, respectively. T1 accuracy was 46.3% at Lag 1, 82.7% at Lag 3, and 91.3% at Lag 8. T1 accuracy was 75% in the same color condition, and decreased to 71.8% in the different color condition. A significant interaction effect of Lag and Color was also found, F(1, 32) = 8.25, MSE = .01, p < .01, η2p = .26. Tukey HSD comparisons showed that T1 accuracy at Lag 1 in the same color condition (51.2%) was significantly greater than in the different color condition (41.4%) [t = 6.3, p < .05], while it was not at the other lags.

T2|T1 Accuracy: Overall T2 accuracy was 51.2%. Lag and Color affected T2|T1 accuracy significantly, F(2, 36) = 45.32, MSE = .05, p < .001, η2p = .65; F(1, 24) = 9.86, MSE = .01, p < .01, η2p = .29, respectively. T2|T1 accuracy was 51.5% at Lag 1, increased to 67.7% at Lag 3 and further increased to 86.9% at Lag 8. T2|T1 accuracy was 65.9% in the same color condition and increased to 71.5% in the different color condition. Furthermore, Lag and Color had a significant interaction effect, F(1, 24) = 22.82, MSE = .01, p < .001, η2p = .49. Tukey HSD pairwise comparison results showed that T2|T1 accuracy at Lag 1 in the different color condition (61.4%) was significantly greater than in the same color condition (41.6%) [t = 9.9, p < .01], but not at the other lags.

Temporal Integration: A significant main effect of Color was found on temporal integration frequency, t(24) = 2.4, p < .05, Cohen's d = .44. Temporal integration averaged 19.4% in the different color condition, compared to just 10.8% in the same color condition.

Order Reversals: Similar to temporal integration, order reversals in the different color condition (11.0%) were significantly more frequent than in the same color condition (6.1%), t(24) = 3.7, p < .001, Cohen's d = .75.

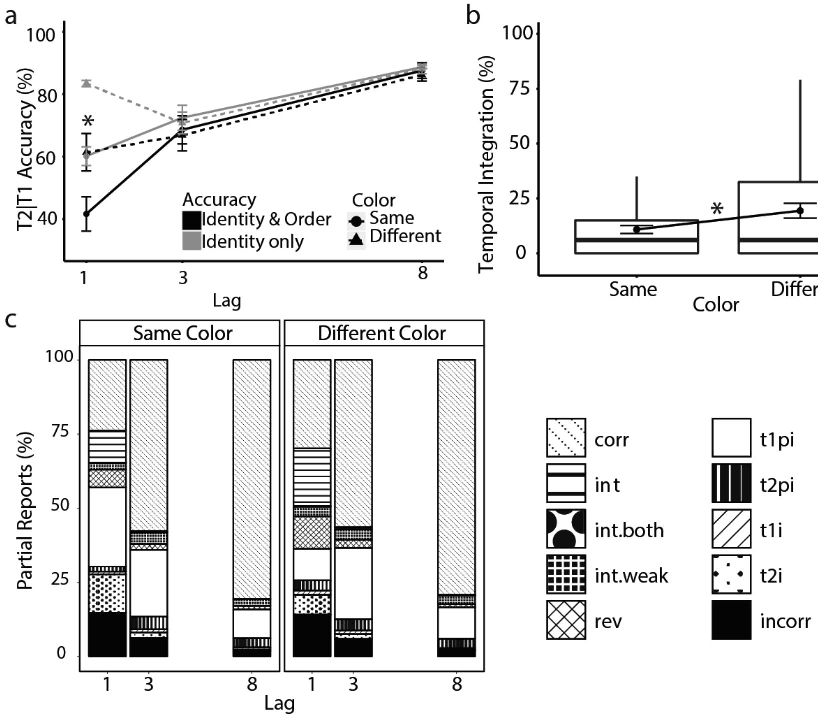


Fig. 2.2. Task performance in Experiment 1A. Error bars represent ±SEM. ***a.*** *T2|T1 performance as a function of Lag. Black lines indicate that both identity and report order of the targets were taken into account (T2 performance given that T1 was identified correctly, in percent correct). Grey lines indicate that order information of targets was ignored. Thus, the trials where T1 identity was correctly reported, regardless of its temporal position (including integrations) were filtered and on that basis T2 identification accuracy including integrations are presented in percent correct.* ***b.*** *Percentage of temporal integration of T1 and T2 at Lag 1.* ***c.*** *Partial reports in Experiment 1A. All variables are shown in %. corr indicates correct responses for both targets; int indicates temporal integration of targets at one of the response prompts with the additional requirement that no response was given at the other response prompt; int.both means that the integrated percept of targets was reported at both response prompts; int.weak indicates that the integrated percept was reported at one of the response prompts and an incorrect response (corresponding to neither target) was reported at the other response prompt; rev indicates order reversal of targets, when T1 was reported as T2 and vice versa; t1pi means only T1 was identified correctly at the correct response prompt; and t2pi means that only T2 was identified correctly at the correct response prompt; t1i indicates that only T1 identity was reported correctly but at the wrong response prompt; t2i indicates that only T2 identity was reported correctly but at the wrong response prompt; and incorr indicates both responses were incorrect. Asterisks indicate significance in panels a and b; for panel a (black lines), the asterisk reflects the interaction effect of Color and Lag.*

2.4. Experiment 1B

Experiment 1A provided evidence that targets of different colors were more often integrated than targets of the same color, and that T2|T1 identification accuracy was similarly enhanced at Lag 1. This outcome suggested that the same-color target pairs triggered a segregation response from the perceptual system, possibly in an attempt to maintain episodic distinctiveness. This account will be detailed further in the General Discussion. However, it seemed important to determine whether this effect was related to the categorical difference in terms of target hues (i.e., red and blue), or whether any spectral difference might suffice. Experiment 1B was thus implemented in order to further investigate whether a within-category change in color would induce a similar effect on T2|T1 identification accuracy and temporal integration. In this experiment, instead of comprising a category-level change in color (red to blue or vice versa), the color of the target stimuli changed within a single color range (shades of blue).

2.4.1. Method

Experiment 1B was identical to Experiment 1A, except for the following changes.

2.4.1.1. Participants

A new set of 31 students (13 females) participated in the study (mean age = 20.58, range = 18 – 25), meeting the same selection criteria as those of Experiment 1A.

2.4.1.2. Stimuli

The red color stimuli were replaced with a more faded shade of blue (RGB 96, 96, 160; 49 cd/m2).

2.4.1.3. Design and Analysis

In Experiment 1B, the same color condition thus comprised two targets in pure blue or in faded blue, while the different color condition comprised one pure and one faded blue target.

2.4.2. Results

T1 Accuracy: Overall T1 accuracy was 91% in one-target trials. There was neither a main effect of Color nor an interaction of Color and Lag on T1 accuracy in two-target trials ($F < .4$). A main effect of Lag existed on T1 accuracy, $F(1, 43) = 243.68$, MSE = .02, $p < .001$, η2p = .89. T1 accuracy averaged 51.5% at Lag 1, compared to 85.7% at Lag 3, and 91.1% at Lag 8.

T2|T1 Accuracy: Overall T2 accuracy was 61.0%. Only Lag influenced T2|T1 accuracy significantly, F(2, 60) = 47.84, MSE = .02, $p < .001$, η2p = .62. T2|T1 accuracy was 66% at Lag 1, increased to 77.2% at Lag 3, and further increased to 88.8% at Lag 8. No reliable main effect of Color, nor an interaction of Color with Lag was found to affect T2|T1 accuracy (F < 1.49).

Temporal Integration and Order Reversals: There were no significant differences in temporal integration and order reversals between the target color pairs at Lag 1 (t(30) < .9).

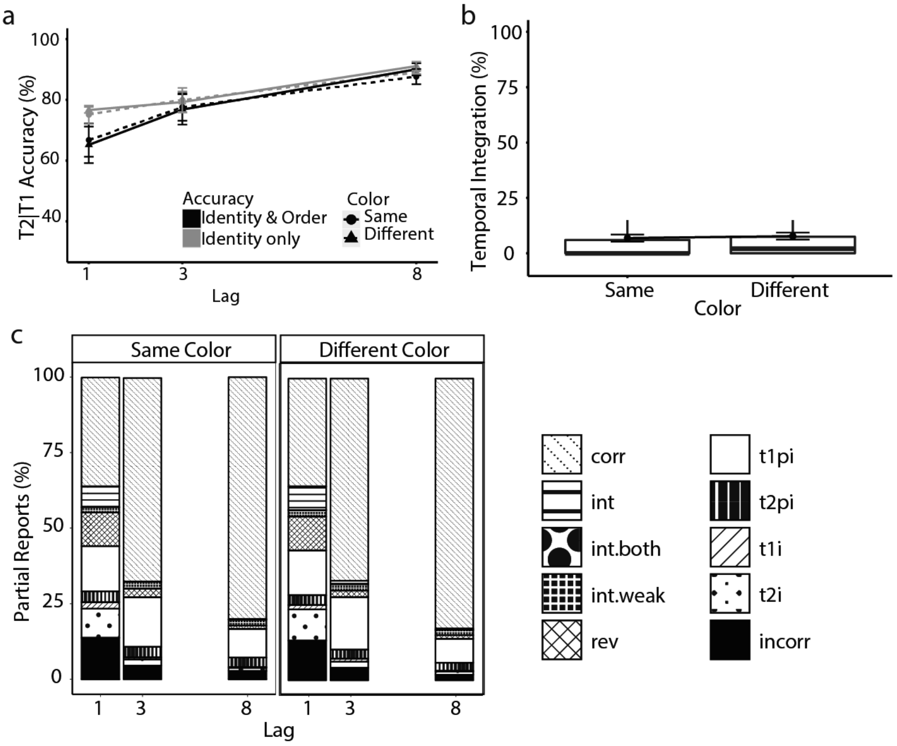


Fig. 2.3. Task performance in Experiment 1B. Error bars represent ±SEM. ***a.*** *T2|T1 performance as a function of Lag.* ***b.*** *Frequency of temporal integration (%) of T1 and T2 at Lag 1.* ***c.*** *Partial reports of Experiment 1B. Labels and asterisks follow Figure 2.2.*

2.5. Experiment 1C

The outcome of Experiment 1B suggested that the effects of target color pairs obtained in Experiment 1A were indeed due to the categorical difference in color in the latter experiment. Apart from this stimulus-based factor, another aspect of the design of Experiment 1A might have facilitated the effects. Specifically, the experiment featured a blocked design in which color pairings were not mixed between trials. It is thus possible that the effects were wholly or in part due to endogenous control strategies. To examine this possibility, Experiment 1C was conducted to replicate the results of Experiment 1A with a modified design. Instead of implementing the color manipulation in blocked fashion, we used a randomized design this time. As indicated, in block designs, learning and task adaptation might contribute to differences between conditions, which can be assessed by comparing the results to a randomized design in which these factors cannot play a (condition-specific) role. We also added a third color (green) to further generalize and test whether the findings, especially with regard to temporal integration, were replicable.

2.5.1. Method

Experiment 1C was identical to Experiment 1A with the following changes.

2.5.1.1. Participants

A new group of 29 students (19 female) participated in the study (mean age = 21.14, range = 18-44), meeting the same selection criteria as those of Experiment 1A.

2.5.1.2. Apparatus and Stimuli

A third color, green (RGB 0, 120, 0; 46 cd/m2), was added. Stimuli were presented on a 19" CRT monitor (Iiyama HM903DT). The visual angle of the stimuli was 2.01° by 2.01°.

2.5.1.3. Procedure

There were two blocks and each block consisted of 260 experimental trials. 7.7% of the trials included only one target, in 46.2% of the trials the second target was presented at Lag 1, and in 23.1% of the trials each, the second target appeared at Lag 3 and 8. Color pairs now included green and were randomized but equally distributed within a block.

2.5.2. Results

T1 accuracy: Overall T1 accuracy was 74% in one-target trials. Lag and Color both significantly influenced T1 accuracy in two-target trials, F(1, 31) = 205,82, MSE = .03, $p < .001$, $\eta 2p$ = .88; F(1, 28) = 86.63, MSE = .01, $p < .001$, $\eta 2p$ = .76, respectively. T1 accuracy averaged 37.9% at Lag 1, 77.5% at Lag 3 and 84.0% at Lag 8. T1 accuracy averaged 72.6% in the same color condition and decreased to 60.3%

in the different color condition. A significant two-way interaction of Lag and Color was also found, F(1, 37) = 5.38, MSE = .01, $p < .05$, $\eta 2p = .16$. At Lag 1, T1 accuracy was 49.6% in the same color condition and decreased to 43.5% in the different color condition [t = 7.7, $p < .01$]. Moreover, T1 accuracy was also higher in the same color condition at both Lag 3 (82.2% vs. 72.1%) and Lag 8 (92.1% vs. 75.9%) [t = 8.1, $p < .01$; t = 12.3, $p < .01$].

T2|T1 accuracy: Overall T2 accuracy was 48.8%. Lag and Color had significant main effects on T2|T1 accuracy, F(1, 36) = 65.27, MSE = .05, $p < .001$, $\eta 2p = .70$; F(1, 28) = 16.49, MSE = .02, $p < .001$, $\eta 2p = .37$, respectively. T2|T1 accuracy was 49.2% at Lag 1, increased to 71.5% at Lag 3 and further increased to 87.8% at Lag 8. T2|T1 accuracy in the same color condition averaged 65.6%, compared with 73.4% in the different color condition. There was a significant two way interaction of Color and Lag as well, F(1, 41) = 9.63, MSE = .02, $p < .01$, $\eta 2p = .26$. At Lag 1, T2|T1 accuracy averaged 58% in the different color condition, compared to 40.4% in the same color condition [t = 7.5, $p < .01$], while the differences at the longer lags were unreliable.

Temporal Integration: A significant main effect of Color on temporal integration existed, t(28) = 3.4, $p < .01$, Cohen's d = .51. As previously observed in Experiment 1A, at Lag 1, temporal integration in the same color condition was clearly lower than in the different condition (16.7% vs. 26.9%).

Order Reversals: Color did not influence order reversals at Lag 1 (t(28) < .2).

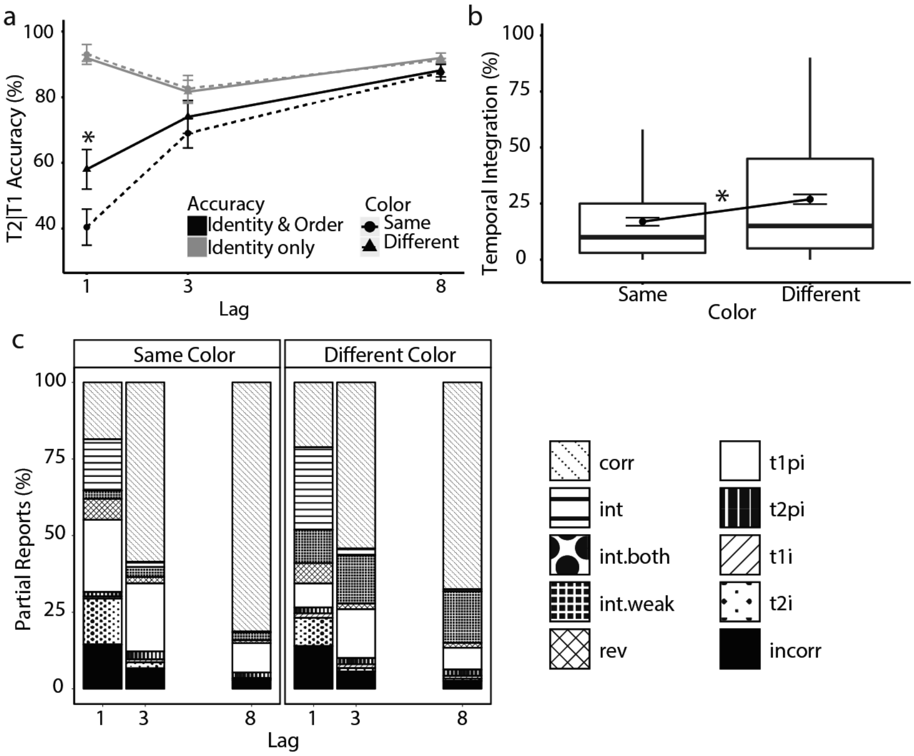


Fig. 2.4. Task performance in Experiment 1C. Error bars represent ±SEM. a. T2|T1 performance as a function of Lag. b. Frequency of temporal integration (%) of T1 and T2 at Lag 1. c. Partial reports of Experiment 1C Labels and asterisks follow Figure 2.2.

2.6. Discussion of Experiment 1

Experiments 1A and 1C were identical to each other in terms of the research question, with only slight differences in design (blocked vs. randomized design, and 2 colors vs. 3 colors). The results of these two experiments were consistent. The results showed that overall T2|T1 accuracy in the different color condition, and the accuracy at Lag 1 in particular was greater than in the same color condition in both experiments, albeit at the expense of reduced T1 accuracy. These findings replicate the previous study of Akyürek, Schubö, and Hommel (2013), in a design without spatial switching.

Importantly, the frequency of temporal integration in the different color condition was significantly greater than in the same color condition in both Experiment 1A and Experiment 1C, with the means showing substantial differences. It bears repeating that actual, individual targets never comprised multiple colors, in either experiment. The perception of integrated, multi-colored targets was thus completely illusory, and not induced by the actual stimuli.

There appeared to be one negative consequence of different color target pairs: T1 accuracy seemed to suffer. However, since these T1 reports concern separate, order-correct responses, they do not reflect shifts in other response categories. In particular, it might be argued that the increased frequency of integrations cannibalized correct single-T1 reports. Indeed, if correct T1 performance would include integrations and order errors (cf. T2 performance), that measure would also show higher T1 performance in the different color condition.

Finally, Experiment 1B differed from Experiments 1A and 1C in terms of the change in color. Instead of a categorical color change, a change within a single color spectrum was tested. This experimental manipulation resulted in notably different outcomes than those of Experiment 1A and 1C. T2|T1 accuracy and temporal integration were not at all influenced by target color pairs. This outcome supports the idea that for a color pair to enhance T2|T1 accuracy and temporal integration, the colors of the targets should likely differ categorically. One caveat with Experiment 1B should nonetheless be mentioned. Although the different color shades were clearly distinguishable on screen, as also confirmed by informal comments made by some of the participants, the results cannot completely exclude the possibility that target dissimilarity was simply too small to notice. This limitation is inherent to the manipulation, which is necessarily more restricted in color space. Experiment 2 further investigates the possible impact of overall visibility by manipulating stimulus contrast.

2.7. Experiment 2A

The effects observed in Experiments 1A and 1C were so far attributed to a category-level change in color between target pairs. This might be justified by the fact that colors are known to lie on a metathetic continuum, rather than a prothetic one. However, an alternative explanation might be that the difference between the colors was simply large, and that any clearly mismatched target pair would elicit similar responses. In order to check this alternative account, in Experiment 2, a strong difference between targets was introduced in terms of contrast. Contrast (mis)matching between targets is in one way similar to the color manipulation from Experiment 1, in that it visually alters the similarity of the targets. At the same time, contrast is prothetic whereas color is metathetic. Comparison of color and contrast thus allows a characterization of the extent to which the effects are due to overall stimulus similarity, or to color-specific processing.

2.7.1. Method

Experiment 2 was identical to Experiment 1 with the following changes.

2.7.1.1. Participants

A new set of 25 students (19 female) participated in the study (mean age = 20.6, range = 18-29). All participants reported normal/corrected-to-normal vision. One female participant was omitted from the analysis because she stated having an attentional deficit disorder.

2.7.1.2. Stimuli

Distractor stimuli were presented in white (324 cd/m2) in order to prevent confusion between target stimuli and distractors. Target stimuli were the same figures as used before, but now rendered in either dark gray (low contrast; RGB 128,128,128; 73 cd/m2) or black (high contrast; RGB 0,0,0; 7 cd/m2).

2.7.1.3. Procedure

In one of the blocks, T1 and T2 had the same contrast (i.e., both were low contrast or both high contrast) while in the other block T1 and T2 had different contrast (i.e., low-high or high-low contrast).

2.7.1.4. Design and Analysis

In the analysis of the contrast effect, Contrast had two levels: Same contrast and different contrast. As before, a more stimulus-specific secondary analysis was also carried out, separating both T1 contrast (low/high contrast) and T2 contrast (low/high contrast), which is presented in the Appendix 1.

2.7.2. Results

T1 Accuracy: Overall target accuracy in one-target trials was 89.7%, and overall T1 accuracy in two-target trials was 69.2%. Main effects of Lag and Contrast were found on T1 accuracy, F(2, 35) = 180.75, MSE = .001, $p < .001$, $\eta 2p = .89$; F(1, 23) = 229.53, MSE = .001, $p < .001$, $\eta 2p = .91$, respectively. T1 accuracy averaged 71.3% at Lag 1, increased to 87.4% at Lag 3 and 92.7% at Lag 8. T1 accuracy was 92.0% in the same contrast condition and decreased to 75.6% in the different contrast condition. Furthermore, a significant interaction effect of Lag and Contrast was found, F(1, 32) = 193.47, MSE = .01, $p < .001$, $\eta 2p = .89$. Pairwise comparisons showed that T1 accuracy in the same contrast condition at Lag 1 (93.9%) was significantly higher than in the different contrast condition (48.7%) [$t = 9.9$, $p < .01$].

T2|T1 Accuracy: Overall T2 accuracy was 58.9%. T2|T1 accuracy was affected significantly by Lag and Contrast, F(2, 46) = 17.56, MSE = .05, $p < .001$, $\eta 2p = .43$; F(1, 23) = 4.87, MSE = .01, $p < .05$, $\eta 2p = .18$, respectively. T2|T1 accuracy averaged 66.9% at Lag 1, 71.2% at Lag 3 and 90.8% at Lag 8. Furthermore, T2|T1 accuracy was 78.1% in the same contrast condition, compared to 74.5% in the different contrast condition. The interaction term was unreliable (F < 1.5).

Temporal Integration and Order Reversals: Contrast influenced neither temporal integration nor order reversals significantly (t(23) < .9).

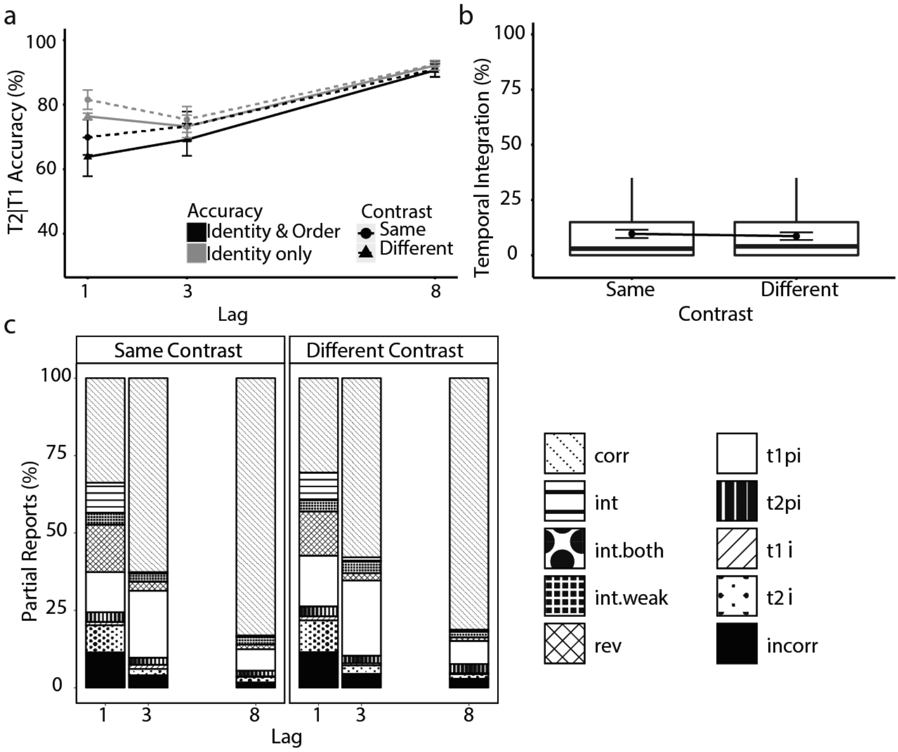


Fig. 2.5. Task performance in Experiment 2A. Error bars represent ±SEM. ***a.*** *T2|T1 performance as a function of Lag.* ***b.*** *Percentage of temporal integration of T1 and T2 at Lag 1.* ***c.*** *Partial reports of Experiment 2A. Labels follow Figure 2.2.*

2.8. Experiment 2B

Following the motivation for Experiment 1C, Experiment 2B was conducted to replicate the observed effects of Experiment 2A with a randomized design, investigating the possible contribution of endogenous control processes.

2.8.1. Method

Experiment 2B was identical to Experiment 2A with the following changes.

2.8.1.1. Participants

24 new students (10 female) participated in the study (mean age = 21.5, range = 19-29), meeting the same criteria as those in Experiment 2A.

2.8.1.2. Apparatus

The operating system in the laboratory was updated so that this experiment was run under Windows 10.

2.8.1.3. Design

A randomized design was used instead of a blocked design.

2.8.2. Results

T1 accuracy: Mean T1 accuracy was 92.0% in one-target trials, and 71.5% in two-target trials. Only Lag had a main effect on T1 accuracy, F(1, 27) = 204.19, MSE = .02, p < .001, η2p = .90. T1 accuracy was 51.4% at Lag 1, increased to 87.2% at Lag 3 and further increased to 92.9% at Lag 8. The main effect of Contrast, as well as the interaction term, were unreliable (F's < 1).

T2|T1 Accuracy: Overall T2 accuracy was 57.5%. T2|T1 accuracy was significantly influenced by Lag and Contrast, F(2, 46) = 27.50, MSE = .04, p < .001, η2p = .54; F(1, 23) = 22.05, MSE = .001, p < .001, η2p = .49, respectively. T2|T1 accuracy averaged 64.3% at Lag 1, increased to 70.9% at Lag 3 and 92.0% at Lag 8. T2|T1 accuracy averaged 77.6% in the same contrast condition compared to 73.8% in the different contrast condition. The interaction of Contrast and Lag did not influence T2|T1 accuracy (F < 1.9).

Temporal Integration and Order Reversals: Paired sample t-tests showed no significant effects of Contrast on temporal integration and order reversals (t(23) < .9).

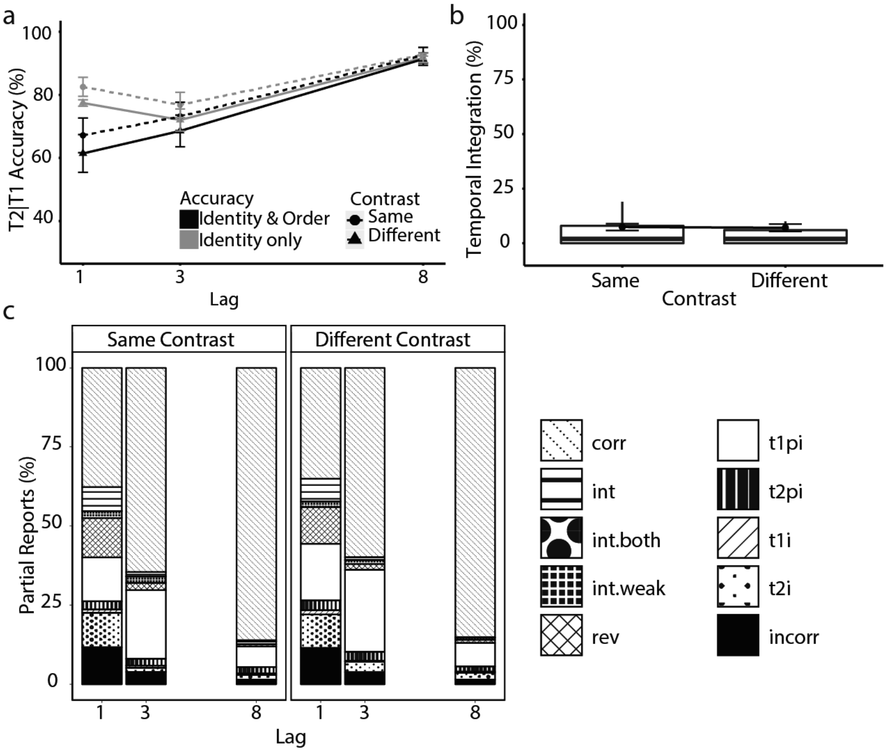


Fig. 2.6. Task performance in Experiment 2B. Error bars represent ±SEM. ***a.*** *T2|T1 performance as a function of Lag.* ***b.*** *Percentage of temporal integration of T1 and T2 at Lag 1.* ***c.*** *Partial reports of Experiment 2B. Labels follow Figure 2.2.*

2.9. Discussion of Experiment 2

The findings of Experiment 2A and 2B clearly differed from those of Experiments 1A and 1C. First, as might have been expected, masking effects seemed to take their toll on T1 performance in Experiment 2A and 2B; lower accuracy was found in the different contrast condition at Lag 1. As supported by the secondary individual target contrast-specific analyses (see the Appendix 2), the different contrast condition provided more opportunity for masking to have an impact, particularly when a high contrast T2 followed a low contrast T1. This masking effect was not obtained for the color pairs of Experiment 1, which supported the idea that the difference in stimulus strength, caused by the contrast manipulation, was the primary cause of this effect.

Second, the results of Experiments 2A and 2B also showed higher T2|T1 accuracy in the same contrast condition than in the different contrast condition, which was diametrically opposed to the results of Experiment 1. This might be explained by assuming that a decrease in target saliency would disrupt the processing of T2. Specifically, there was a decrease in T2|T1 accuracy when a low contrast T2 followed a high contrast T1. That decrease was not only a result of stimulus strength (i.e., a forward masking effect) because there was a slight decrease of T2|T1 accuracy when both targets were low contrast, compared to when both of them were high contrast. Hence, it must have been a decrease in T2 saliency, relative to T1, that specifically disrupted information processing (see Appendix 2 for means and F values).

Third, and constituting the most notable difference between Experiments 1A and 1C on the one side and Experiments 2A and 2B on the other, was that there were no effects whatsoever of target contrast pairs on the frequency of temporal integration and order reversals. Although overall target identification accuracy was clearly moderated by the contrast manipulation, it is important to note that, despite this variation, the performance was not at a level that would be expected to preclude integration effects. Integration in same-color and same-contrast conditions was indeed similar overall. The lack of an integration effect for different contrast pairs thus supports the conclusion that the categorical color effect observed in Experiments 1A and 1C cannot be attributed to general stimulus dissimilarity.

2.10. General Discussion

We investigated the effects of matching color and contrast between target pairs on temporal attention and integration in RSVP. To a considerable degree, the color and contrast manipulations caused opposite effects. The principal outcomes of the present experiments can be summarized as follows: First, the results showed that targets with different categorical colors improved T2|T1 identification accuracy (Experiments 1A and 1C), particularly at Lag 1, while a non-categorical change in color (Experiment 1B) did not moderate T2|T1 accuracy. Different contrasts (Experiments 2A and 2B) produced an opposite effect and decreased overall T2|T1 accuracy. Second, targets with different colors were more frequently integrated and more order errors between them were made while targets with different contrasts and targets with a non-categorical color difference (i.e., different shades of blue) were not. Third, all but one of these effects were independent of any (learned) strategic allocation of attention, as the effects replicated regardless of whether the manipulations were implemented in a blocked or randomized fashion. The increase in order reversals at Lag 1 when targets had different colors was the only thing that disappeared when color matching was randomized (Experiment 1C), suggesting it was a result of strategic endogenous control afforded in the blocked design (Experiment 1A).

2.10.1. Color-based target matching

Superficially, the present manipulations of color and contrast may be viewed as ways to vary target similarity. The outcomes clearly indicated that this conception is too simplistic. Target processing did not depend on overall similarity across the present experiments, but on the specific manipulation. The differential effects of color and contrast matching support the more general hypothesis that feature-specific processing should play a role in temporal attention and integration. This fits with theories of the AB that make a similar assumption, such as the (e)STST model by Wyble and colleagues (2007; 2009). On the basis of this model, it could be argued that increased featural similarity should reduce episodic distinctiveness between targets. Because the attentional suppression that is reflected in the AB is an attempt of the perceptual system to keep targets apart, it then makes sense that the increased featural similarity between targets of the same, or a similar, color should result in a need for more (or longer) suppression and an increased AB. In a way, this is reminiscent of the increased difficulty of visual search when targets and distractors share task-relevant features and need to be discriminated (Duncan & Humphreys, 1989).

Temporal integration frequency was also affected by color matching between targets, so that mismatched pairs were more often integrated. This fits with our previous research (Akyürek, Schubö, & Hommel, 2013) in which spatially displaced targets of the same color were observed to interfere with recall at Lag 1. Although the spatial displacement might have mediated that effect, it is compatible with the idea of episodic distinctiveness (Wyble et al., 2007; 2009). The outcomes of the current task extend these previous findings and suggest that two same/similar-color targets trigger a rapid segregation response even at a single location, which is possibly attentional in nature, and which specifically works against the tendency to temporally integrate the targets.

If integration behavior is indeed related to an attempt to dissociate two featurally similar targets, this also implies that some part of the integration process in RSVP may be affected by attentional factors. As previously suggested by Akyürek and Wolff (2016), this might be due to the contributions of higher level processes, which has been referred to as informational persistence, as opposed to the lower level factor of visible persistence (Coltheart, 1980; Di Lollo, 1980; Loftus & Irwin, 1998). Evidence from event-related potentials related to temporal integration in RSVP has implicated working memory-related components (i.e., the P3 and the contralateral delay activity [CDA]), suggesting a relatively late locus (Akyürek, Kappelmann, Volkert, & van Rijn, 2017). In this context, it must nonetheless be pointed out that the currently observed frequency of integration was not related to having a blocked or randomized design, suggesting that endogenous, strategic control was not mediating the integration effect, which was the case for order reversals despite the apparently late locus of temporal integration in the processing stream. This discrepancy in control over integration and order reversals may have arisen because, in the current task, the latter report error can be disambiguated from integration and attributed exclusively to attentional priority processing (see also Hilkenmeier, Olivers, & Scharlau, 2012).

The combined facilitatory effects on target identification and integration that were presently found may be related to findings from studies of spatial attention. On the one hand, if observers perform a visual search task by looking for a particular feature (e.g., color) an increase in neural responses is observed for that any occurrence of that feature, even far from the locus of attention (e.g., Saenz, Buracas & Boynton, 2002), following a coarse-to-fine selectivity profile over time (Bartsch et al., 2017). On the other hand, inhibitory effects are also frequently associated with attention, such as the suppressive surround regions that are commonly observed just outside the locus of attention (e.g., Hopf et al., 2006). Importantly, similar inhibition effects are also observed in feature space. Störmer and Alvarez (2014) showed that colors in the visual field that were similar (though not identical) to an attended color were attentionally suppressed. A similar inhibitory interaction may also have played a role in the current temporal task: A repeated encounter of a feature that is similar to one that was previously targeted may produce an inhibitory response, if it occurs close in time. The idea that a spatial inhibitory surround should help shield the target from potentially confusing neighboring signals (Störmer and Alvarez, 2014) may thus similarly apply in time, which also fits with the idea that temporal attention strives to maintain episodic distinctiveness between targets and other, likely irrelevant items (Wyble et al., 2007; 2009). The present results do suggest that there might be a qualitative difference between the temporal and spatial domains, in that the former but not the latter inhibitory effect seems to occur for identical colors.

2.10.2. Contrast-based target matching

As mentioned, in reference to the effects due to color matching, we observed largely opposite effects of target contrast matching. The first effect was that target contrast pairs did not affect integration at Lag 1 (nor order reversals). The lack of a contrast effect might appear to be at odds with previous studies that showed increased order reversal rates when targets had similar contrast (Chua, 2005; Hommel & Akyürek, 2005). Apart from various methodological differences (e.g., ISI, stimulus duration, lag distribution), this might again be related to the fact that integration cannot be measured directly by counting order errors in classic AB tasks (i.e., tasks in which targets cannot be reported in an illusory, combined form). Recall that order error rates in classic tasks reflect both real order errors, possibly mediated by attentional processes (such as prior entry) and integrations, whereas these are kept separate in the current task. Closer inspection of the means (cf. Tables A1.3 and A1.4) suggests that integrations and order reversals exhibited opposite patterns. When T1 contrast was high, there were fewer integrations overall when T2 was high contrast also, compared to when T2 contrast was low. Conversely, there were more order reversals in the former case than in the latter. When T1 contrast was low, there were fewer integrations when T2 contrast was high, compared to when T2 contrast was low, but the opposite was true for order reversals. Interestingly, when considering the sum total of both integrations and reversals, the pattern was similar to that reported by Chua (2005 and Hommel & Akyürek (2005); higher frequencies were observed when both targets had the same contrast than when they did not. However, it must be noted that this similarity was not supported statistically. At present, the only safe conclusion to draw from the present data is that the current task seems to have elicited opposite trends in integrations and reversals in response to contrast. It is conceivable that the visual compatibility of the targets played a role therein, but this issue remains to be studied further.

The second effect was that overall T2|T1 accuracy was actually higher when contrast between targets matched. In line with previous findings (Chua, 2005; Hommel & Akyürek, 2005), target contrast specific analyses (see the Appendix 2) furthermore showed that when T1 contrast was low and T2 contrast was high, increased T2|T1 accuracy was observed. Two factors may have contributed to this effect. First, a salient T2 might capture attention in a bottom-up fashion if its salient feature (i.e., high contrast) is part of the target search template, reducing the AB (e.g., Folk, Leber, & Egeth, 2008). Second, many AB theories assume there exists a trade-off between the 'investment' in T1 and the processing of T2 that might have resulted in the relative success of T2 identification in this condition (e.g., Olivers & Meeter, 2008). That said, however, it should be noted that although the contrast effect seemed more pronounced at shorted lags, the analysis did not provide strong evidence (i.e., from an interaction) that it was indeed AB-specific. Thus, this finding should be interpreted with caution.

From the collective contrast-based results, it seems clear that this manipulation did not trigger the same mechanisms as the color-based manipulation. It thus seems that episodic attentional processing, which comprises both temporal integration at Lag 1 and T2 identification at intermediate lags, is not similarly sensitive to contrast as it is to color, at least in the current task. A parsimonious, comprehensive explanation for this difference is that the color manipulation concerned both a primary visual feature and a change on a metathetic continuum (in Experiment 1A and 1C). Contrast, related to overall brightness, might not only be less of a primary visual feature, but certainly also constitutes a prothethic continuum, in which differences might be processed in a more gradual fashion by definition. Further experiments will nevertheless be needed to elucidate the degree to which these general factors play an overarching role in the perception of episodic distinctiveness in RSVP.

2.11. Conclusion

In sum, the present results suggested a clear dissociation between (categorical) color-based and contrast-based processing. Color dissimilarity between targets in RSVP improved attentional performance and increased temporal integration, whereas contrast dissimilarity decreased overall performance and did not affect integrational processing at Lag 1. It may finally be concluded that color-related, featural information processing affects not only attentional allocation in space, but also attention and integration in time. Further research may consider the question whether other categorical changes (e.g., orientation or location) influence temporal attention and integration in a similar way to color changes.

Acknowledgments

We are thankful to Şafak Horzum for proofreading the article. This research was funded in part by a fellowship from Turkish Ministry of National Education to AK.

Chapter 3

The effects of Kanizsa contours on temporal integration and attention in rapid serial visual presentation

This chapter was previously published as:

Karabay, A., & Akyürek, E. G. (2017). The effects of Kanizsa contours on temporal integration and attention in rapid serial visual presentation. *Attention, Perception, & Psychophysics, 79*(6), 1742–1754. doi:10.3758/s13414-017-1333-6

3.1. Abstract

Performance in rapid serial visual presentation tasks has been shown to depend on the temporal integration of target stimuli when they are presented in direct succession. Temporal target integration produces a single, combined representation of visually compatible stimuli, which is comparatively easy to identify. It is currently unknown to what extent target compatibility affects this perceptual behavior, because it has not been studied systematically to date. In the present study, the effects of compatibility on temporal integration and attention were investigated by manipulating the Gestalt properties of target features. Of particular interest were configurations in which a global illusory shape was formed when all stimulus features were present; a Kanizsa stimulus, which was expected to have a unifying effect on the perception of the successive targets. The results showed that although the presence of a Kanizsa shape can indeed enhance temporal integration, this also was observed for other good Gestalts, such as due to common fate and closure. Identification accuracy seemed to vary, possibly as a result of masking strength, but this did not seem associated with attentional processing per se. Implications for theories of Gestalt processing and temporal integration are discussed.

Keywords: Perceptual Gestalts, Temporal integration, Attentional blink, Rapid serial visual presentation

3.2. Introduction

It could be argued that the load on our sensory systems is increasing day by day due to technological developments. Modern means of transportation allow us to move around at high speed, while the electronic devices that we carry keep us online and in touch with others virtually continuously. Clearly, it is crucial to make the right decisions when it comes to attending to relevant objects and events, and being able to ignore those that are irrelevant—such as the incoming electronic newsletter of a clothing store while you drive.

Attention is a powerful cognitive function that allows us to make such selections. Unfortunately, it also is cognitively costly. A prime example of those costs comes from the so called attentional blink (AB) phenomenon. The AB is the difficulty associated with identifying a second target stimulus, when it occurs in close temporal succession (200-500 ms) after a first target stimulus (Broadbent & Broadbent, 1987; Raymond, Shapiro, & Arnell, 1992; see Dux & Marois, 2009 for review). Although accounts of the AB vary, it is commonly accepted that cognitive costs are incurred to process the first target (T1), because doing so consumes limited cognitive resources, or equivalently, processing time. This then causes the attentional processing of the second target (T2) to suffer (Bowman & Wyble, 2007; Chun & Potter, 1995; Jolicœur & Dell'Acqua, 1998; Olivers & Meeter, 2008).

The AB typically has been studied in rapid serial visual presentation (RSVP) tasks, in which brief visual stimuli follow and thereby mask each other in the center of a screen. Apart from the AB, such tasks have shown that the length of the time interval that is processed as one single event by the perceptual system can have consequences for the effort needed to process the ongoing stream. This special status of perceptual events was first derived from the analysis of performance when targets in RSVP follow each other directly, at minimal stimulus onset asynchrony, without distractors in-between. In such cases, the identification of T2 often is quite good, which is called sparing, to indicate the apparent escape from the AB (for review, see Visser, Bischof, & Di Lollo, 1999). Crucially, sparing is often accompanied by a marked increase in target report order errors. This finding has prompted the idea that the two successive targets may have fallen into a single perceptual episode or event, causing temporal order information between them to be lost (Hommel & Akyürek, 2005). Temporal target integration has subsequently been implicated directly in tasks that allow not only report of individual target stimuli (e.g., / and \) but also of the temporally integrated percept of these targets (i.e., X), which confirmed that temporal integration drives task performance to a substantial degree at short inter-target lags (Akyürek et al., 2012; Akyürek & Wolff, 2016).

It has to be noted that alternative accounts of order reversals and sparing at Lag 1 have been put forth (Olivers, Hilkenmeier, & Scharlau, 2011; Olivers &

Meeter, 2008; Wyble, Bowman, & Nieuwenstein, 2009), which propose that an attentional prior entry effect may explain both the preponderance of order errors and the comparatively high level of target identification observed at Lag 1. Although Akyürek and colleagues (2012) demonstrated that temporal integration is likely the biggest underlying factor at Lag 1, a smaller portion of trials remained in which true (i.e., not-integrated) order errors were observed and for which attentional effects might play a role.

Evidently, it is important to characterize the circumstances that might foster or, alternatively, prevent attentional lapses, whether they are due to short-term attentional dynamics or due to the temporal integration of targets into perceptual events. Several studies have investigated the possible effects of the stimulus properties that need to be processed on the AB. Various perceptual factors related to visual masking and target difficulty have been found to modulate AB magnitude (Chun & Potter, 1995; Giesbrecht, Bischof, & Kingstone, 2003; Seiffert & Di Lollo, 1997; Visser, 2007; although see also McLaughlin, Shore, & Klein, 2001; Ward, Duncan, & Shapiro, 1997) and to modulate target report order reversal frequency (Akyürek & Hommel, 2005), but none have considered temporal integration at Lag 1 specifically. To do so was the purpose of the present study.

For temporal integration, the visual compatibility of the successive targets is arguably paramount. At a basic level, if targets spatially overlap to a large extent, disruptive masking may result, in which the succeeding target at least partially overwrites the preceding one, particularly when targets are visually unfamiliar (for review, Enns & Di Lollo, 2000). Conversely, when the targets form a good figure together, their temporal integration may be facilitated. Good figures are governed by so-called Gestalt laws, which are known to exert a strong influence on perception (Wertheimer, 1938). A good figure, or Gestalt, is generated by stimulus properties such as proximity, connectedness, closure, symmetry, common fate, and continuity. Stimuli that exhibit such properties are perceptually grouped together in space (for review, Wagemans et al., 2012). Perceptual grouping is exceptionally strong for so-called Kanizsa stimuli, which induce the impression of a single emergent, illusory shape (see Fig. 3.1, stimuli of Experiment 2, for a classic example). Neurophysiological evidence also suggests that perceptual grouping involves processing of both actual and illusory contours, because all of these seem to take place at a relatively early processing stage (Davis & Driver, 1994) and in the same brain regions (V1/V2; Grossberg, Mingolla, & Ross, 1997; Lee, 2002; Murray, Schrater, & Kersten, 2004), although the lateral occipital complex also has been implicated in illusory contour processing (Seghier & Vuilleumier, 2006). Because Kanizsa figures thus enable the spatial integration of separate stimuli at a relatively early stage of visual processing, it seems conceivable that this may also facilitate temporal integration in RSVP.

Similarly, because previous research has provided evidence for object-based effects on temporal attention, Kanizsa figures may affect attentional efficiency, that is, they may modulate blink magnitude at shorter lags. For instance, Kellie and Shapiro (2004; see also Raymond, 2003) showed that object file continuity decreases AB magnitude in a stimulus morphing RSVP paradigm. When the RSVP consisted of a smooth morph of one object into another, blink magnitude was reduced compared with an RSVP in which the same images were presented in random order. The authors reasoned that a single object file (containing both targets) could be maintained in the former case, instead of having to create multiple files in the latter case. Using a multi-stream RSVP task, Conci and Müller (2009) also observed that targets in different streams that were grouped together across space by falling within the same contour region (i.e., within the same object) do not produce the same blink magnitude as targets that were not similarly grouped. This object-based interference effect was even obtained when an occluder was placed across the objects.

Based on these findings, we hypothesized that the figural goodness provided by Kanizsa figures should facilitate temporal integration and enhance or at least interact with attentional efficiency. These hypotheses were tested in a unified paradigm: As a first step, in Experiment 1, target stimuli that were used previously by Akyürek et al. (2012) were tested for possible Kanizsa effects. Subsequent experiments further examined classic Kanizsa-inducing stimulus configurations, contrasting these with configurations composed of identical elements and with varying (non-Kanizsa) Gestalt properties.

3.3. Experiment 1

Experiment 1 was a close replication and extension of Experiment 1 reported by Akyürek and colleagues (2012). This experiment used corner segments for its target stimuli, which form a basic Kanizsa square at their center (Fig. 3.1). To examine the possible effect of that illusory shape, this stimulus configuration was contrasted with another in which the corners were inverted (i.e., rotated by 180°), removing the illusory square while keeping the local, low-level features of the stimuli identical.

3.3.1. Method

3.3.1.1. Participants

Twenty-five (14 females) undergraduate students of the University of Groningen participated in the study in exchange for course credits (mean age 21.2 years, range 18-25). All participants were naïve to the purpose of the study and reported normal/corrected to normal visual acuity. The study was approved by the ethical committee of the Psychology Department of the University of Groningen (approval number 15044NE) and conducted in accordance with the Declaration of Helsinki. Written, informed consent was obtained before participation.

3.3.1.2. Apparatus and stimuli

Participants were seated in a dimly lit sound attenuated testing cabins with a distance of approximately 60 cm from the monitor. Stimuli were presented on a 22" CRT monitor (Iiyama MA203DT). The refresh rate was set to 100 Hz with a resolution of 1280 × 768 pixels at 16-bit color depth. The study was programmed in E-prime 2.0 Professional (Psychology Software Tools) and executed in the Windows 7 operating system. A standard keyboard was used for collecting responses.

Stimuli were presented on a light gray background (RGB 192,192,192). Distractor stimuli were chosen from the full alphabet (excluding O and X), without replacement on each trial. Distractor stimuli were presented in black 52 pt Courier New Font. The fixation cross (+) was presented in the same color in 18 pt font on each trial. Target stimuli consisted of 1-4 corner segments of a square with an area of 50 by 50 pixels (1.85° by 1.85° of visual angle) in the center of the screen (Fig. 3.1) with the constraint that a segment was not repeated in the same trial so that there was no overlap between targets. The number of corners presented for each target was randomized so that the total corner segments of T1 and T2 varied from two to four (e.g., one corner for T1 and another corner for T2, or one corner for T1 and two corners for T2, etc.). The length of each corner segment was 20 pixels (0.74° of visual angle) and the width was 9 pixels (0.33° of visual angle) so that the area of each corner segment was 277 pixels square. The gap between each of the corner segments was 6 pixels (0.22° of visual angle). There were two stimulus conditions; the corner segments either formed an illusory square (Kanizsa-present condition), or did not, because the segments were rotated 180° (Kanizsa-absent condition).

3.3.1.3. Procedure

There were 2 blocks in the experiment, each containing 216 self-paced experimental trials. Each block comprised one stimulus condition (Kanizsa-present or -absent). The order of two blocks was counterbalanced between subjects, and the trials within were randomized. The experiment started with 24 practice trials, which were omitted from analyses. Participants were offered to have a break between two blocks. The duration of the experiment was approximately 45 minutes. Participants started each trial by pressing Enter; 100 ms after pressing Enter, a fixation cross appeared on the screen for 200 ms. Then an RSVP started, accommodating 18 stimuli, each on screen for 70 ms and separated by a 10-ms blank interval. The first target appeared in the fifth or seventh position of the RSVP, which was random but equally distributed. If there was a second target, it followed the first target as the first item (Lag 1), as the third item (Lag 3), or as the eighth item (Lag 8). Seven percent of the trials consisted of only one target. Forty-six percent of the trials were dual target trials with the second target at Lag 1. Twenty-three percent of the trials consisted of dual target trials at Lag 3 and another 23% at Lag 8. Each trial was followed by two successive response prompts. These response prompts asked participants to enter T1 and T2. Participants were able to enter the two targets by pressing keys on the numeric keypad, which corresponded to the spatial locations of the corner segments (1, 2, 4, 5), followed by Enter. Moreover, participants could enter just one target by pressing the related button(s) in one of the response prompts, and only Enter in the other, or they could indicate having seen nothing by pressing Enter directly in both response prompts.

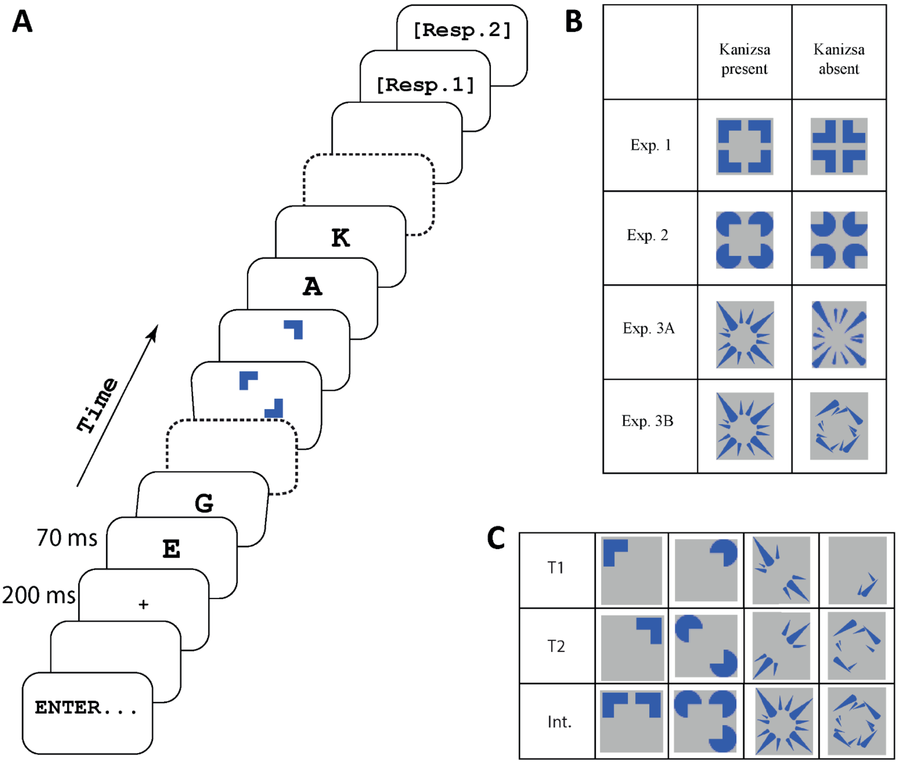


Fig. 3.1. ***a.*** *Illustration of the procedure of experimental task. Letters were used as distractors, and targets appeared among these in the stimulus stream. There was a 10-ms blank interval between stimuli. Resp. refers to response prompt.* ***b.*** *Target stimuli containing all four corner segments. Kanizsa-present and Kanizsa-absent columns show the experimental manipulation of the targets. On each trial, the targets contained one or more corners of these full stimuli (i.e., upper left, upper right, lower left, and lower right quadrants), without mutual overlap.* ***c.*** *Examples of targets and their possible integrations. Int. is an abbreviation of integration.*

3.3.1.4. Design

Repeated measures analyses of variance were conducted with the design consisting of two variables: Lag (T2 lags 1, 3, 8) and Kanizsa (present when the corner segments formed an illusory square, and absent when the inversed corner segments were used). Separate analyses were conducted for T1 and T2 performance (% correct) as well as integration frequency. Unification of T1 and T2 as a single percept was defined as temporal integration. Therefore, the frequency of the exact combination of T1 and T2 as a response in one of the response prompts was calculated, with the added requirement that no response was given at the other prompt. T2 accuracy was measured in the trials on which T1 was reported correctly (T2|T1), as is commonly done. Greenhouse-Geisser corrected p values are reported when appropriate in all analyses. Tukey HSD tests were conducted in order to further characterize interaction effects.

3.3.2. Results and discussion

Participants correctly reported 85.9% (SEM = 1.5%) of one target trials, 72.8% (SEM = 0.5%) of T1 (Table 3.1) and 64.5% (SEM = 0.4%) of T2 in two target trials. Significant main effects of Lag and Kanizsa on T2|T1 performance existed, $F(1, 27) = 61.03$, $MSE = 0.07$, $p < 0.01$, $\eta 2\ p = 0.72$, and $F(1, 24) = 17.40$, $MSE = 0.01$, $p < 0.01$, $\eta 2\ p = 0.42$, respectively. T2|T1 accuracy and integration frequency are shown in Fig. 3.2. T2|T1 accuracy was 45.6% at Lag 1, increased to 82% at Lag 3, and further increased to 86.4% at Lag 8. T2|T1 accuracy was 67.8% when a Kanizsa contour was present and increased to 74.8% when it was not. A significant interaction effect of Kanizsa and Lag also was found on T2|T1 accuracy, $F(1, 30) = 14.47$, $MSE = 0.01$, $p < 0.01$, $\eta 2\ p = 0.38$. Tukey HSD pairwise comparisons showed that T2|T1 accuracy on trials in which the Kanizsa was absent was significantly greater than when a Kanizsa shape was present at Lag 3 and Lag 8, but not at Lag 1, HSD = 8%, $p < 0.05$.

Table. 3.1. Average T1 identification performance (% correct) and significant effects (indicated by asterisk symbols) observed in Experiments 1, 2, 3A, and 3B

		Lag 1		Lag 3		Lag 8		*F*	
		Mean	*SEM*	Mean	*SEM*	Mean	*SEM*	Kanizsa	Lag×Kanizsa
Exp. 1	Kanizsa-present	42.0	3.2	79.4	1.2	81.8	1.1	128.3*	.3
	Kanizsa-absent	51.3	3.4	89.4	2.0	82.5	1.4		
Exp. 2	Kanizsa-present	37.0	3.6	92.9	1.4	95.5	1.5	6.3*	14.37*
	Kanizsa-absent	47.0	3.1	91.4	2.0	95.8	1.3		
Exp. 3A	Kanizsa-present	32.7	4.6	86.4	4.5	90.3	4.2	16.8*	2.5
	Kanizsa-absent	25.5	4.8	83.5	5.4	86.5	5.4		
Exp. 3B	Kanizsa-present	37.3	5.0	86.0	3.4	92.4	1.9	14.2*	.9
	Kanizsa-absent	27.5	3.6	80.1	3.8	84.6	3.2		

Because T1 and T2 were shown in direct succession only at Lag 1, it was expected that integration of T1 and T2 would be more frequent at Lag 1. Indeed, Lag had a significant main effect on temporal integration, $F(1, 24) = 29.41$, $MSE = 0.03$, $p < 0.01$, $\eta 2\ p = 0.55$. Temporal integration at Lag 1 was 15.4% and decreased to 1% at Lag 3 and further decreased to 0.2% at Lag 8. Neither the main effect of Kanizsa, nor its interaction with Lag were significant.

Although there was a difference in T2|T1 accuracy at Lag 3 between the Kanizsa conditions, it seemed unrelated to attention, in view of the very similar difference observed at Lag 8, which is well outside the interval affected by the attentional blink. Thus, the results of Experiment 1 provided little evidence to suggest the presence of a Kanizsa contour might have affected the efficiency of temporal attention, nor the frequency of integration. The findings of Akyürek and colleagues (2012) should generalize across non-Gestalt stimuli.

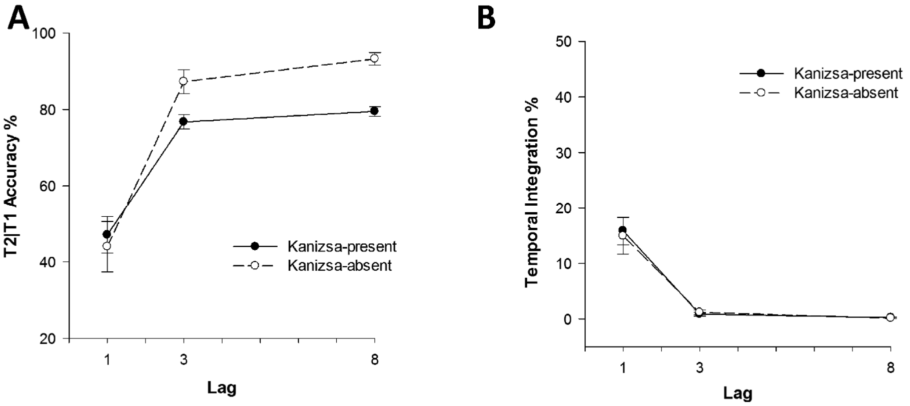


Fig. 3.2. Task performance in Experiment 1 as a function of lag. Error bars represent ±SEM. ***a.*** *T2 | T1 performance (T2 performance given that T1 was identified correctly in percent correct).* ***b.*** *Percentage of temporal integration of T1 and T2.*

3.4. Experiment 2

The Kanizsa condition of Experiment 1 was intended to further scrutizine previous work (Akyürek et al., 2012), but its stimulus configuration does not strongly induce a Kanizsa shape. Thus, to test more directly whether the presence of a Kanizsa figure could principally affect temporal integration and attention, the classic Kanizsa-inducing stimulus configuration of converging Pac-man circles was chosen in Experiment 2 (Fig. 3.1).

3.4.1. Method

Experiment 2 was identical to Experiment 1 with the following exceptions.

3.4.1.1. Participants

Twenty-five (21 females) new students participated in the study (mean age 20.36 years, range 18-26).

3.4.1.2. Apparatus and stimuli

Stimuli were presented on a 19" CRT monitor (Iiyama HM903DT). Stimuli were composed of (maximally) four circles with a triangular incision, known to produce a Kanizsa square when oriented appropriately (Fig. 3.1). The radius of the circles was 11 pixels (0.37° of visual angle) so that its area was 285 pixels square, and the distance between neighboring circles was 6 pixels (0.20° of visual angle). Similar to the procedure of Experiment 1, to implement the Kanizsa-absent condition, the stimuli were rotated 180 degrees.

3.4.2. Results and discussion

The overall T1 accuracy in one target trials was 91.5% (SEM = 1.3%), and in two target trials T1 accuracy was 68% (SEM = 0.5%; Table 3.1), and T2 accuracy was 56% (SEM = 0.5%). Similar to Experiment 1, Lag and Kanizsa had significant main effects on T2|T1 accuracy, $F(1, 25) = 98.34$, $MSE = 0.08$, $p < 0.01$, $\eta2$ p = 0.80, and $F(1, 24) = 45.09$, $MSE = 0.01$, $p < 0.01$, $\eta2$ p = 0.65, respectively. T2|T1 accuracy was 43.9% at Lag 1, 92% at Lag 3, and 95.2% at Lag 8. As shown in the left panel of Fig. 3.3, T2|T1 accuracy was 82.6% in the Kanizsa-present condition and decreased to 71.4% in the Kanizsa-absent condition, in contrast to Experiment 1. A significant interaction effect of Lag and Kanizsa on T2|T1 performance existed, $F(1, 26) = 49.97$, $MSE = 0.01$, $p < 0.01$, $\eta2$ p = 0.68. Tukey HSD pairwise comparisons showed that T2|T1 accuracy at Lag 1 in the Kanizsa-present condition was significantly higher than in the Kanizsa-absent condition at lag 1, HSD = 9%, $p < 0.05$.

Lag and Kanizsa also had significant main effects on temporal integration, $F(1, 24) = 95.47$, $MSE = 0.02$, $p < 0.01$, $\eta2$ p = 0.80, and $F(1, 24) = 18.60$, $MSE = 0.003$, $p < 0.01$, $\eta2$ p = 0.437, respectively. As shown in the right panel of Fig. 3.3, temporal integration averaged 25.4% at Lag 1 and decreased to 1% at Lag 3 and 0.6% at Lag 8. Temporal integration in the Kanizsa-present condition was significantly higher than in the Kanizsa-absent condition. A significant interaction effect of Kanizsa and Lag was found on temporal integration as well, $F(1, 25) = 14.59$, $MSE = 0.01$, $p < 0.01$, $\eta2$ p = 0.38. Pair-wise comparisons showed that temporal integration in the Kanizsa-present condition averaged 29.2% compared with 19.3% in the Kanizsa-absent condition at Lag 1, HSD = 8%, $p < 0.05$.

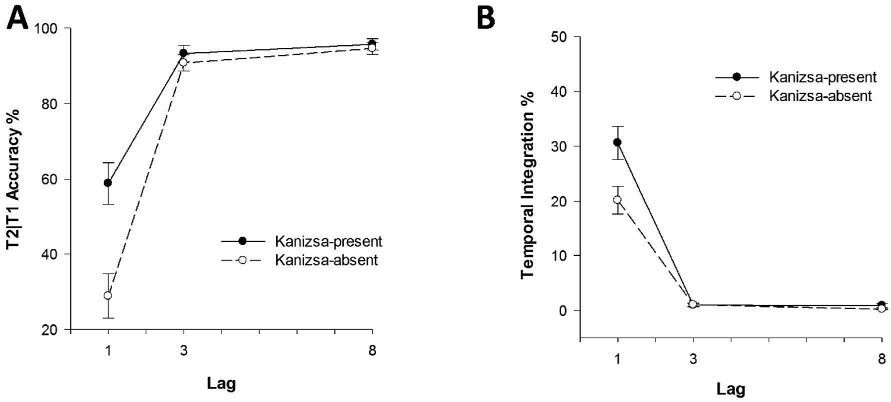


Fig. 3.3. Task performance of Experiment 2 as a function of lag. Error bars represent ±SEM. ***a.*** *T2|T1 performance in percent correct.* ***b.*** *Percentage of temporal integration.*

3.5. Between experiment comparisons

To substantiate further the effects of Kanizsa contours on T2|T1 accuracy and temporal integration frequency, two separate three-way between-subjects analyses comparing T2|T1 accuracy and temporal integration in Experiment 1 and Experiment 2 were performed. Only effects relating to differences between these experiments are reported. T2|T1 accuracy averaged 71.3% in Experiment 1 compared with 77% in Experiment 2. The interaction of Kanizsa and Experiment, as well as the interaction of Kanizsa, Lag and Experiment had significant effects on T2|T1 accuracy, F(1, 48) = 59.02, MSE = 0.01, $p < 0.01$, η2 p = 0.55, and F(1, 58) = 5.23, MSE = 0.01, $p < 0.01$, η2 p = 0.10, respectively. T2|T1 accuracy in the Kanizsa-present condition in Experiment 2 was 82.6% and significantly higher than the average of 67.8% observed in Experiment 1, HSD = 10.3%, $p < 0.05$. Post-hoc tests showed that T2|T1 accuracy in the Kanizsa-present condition of Experiment 2 was significantly greater than in Experiment 1 at each lag (1, 3, and 8). At the same time, T2|T1 accuracy in the Kanizsa-absent condition at Lag 1 in Experiment 1 averaged 44% compared with 28.9% in the same condition of Experiment 2, HSD = 9.2%, $p < 0.05$.

With regard to temporal integration, significant interactions of Experiment and Kanizsa, F(1, 48) = 8.68, MSE = 0.002, $p < 0.01$, η2 p = 0.19, and of Experiment, Kanizsa and Lag were found, F(1, 50) = 7.60, MSE = 0.004, $p < 0.01$, η2 p = 0.14. Integration frequency in the Kanizsa-present condition of Experiment 2 was significantly higher than in either Kanizsa condition of Experiment 1, HSD = 4.4%, $p < 0.01$. At Lag 1, temporal integration in the Kanizsa-present condition of Experiment 2 averaged 29.2% compared with 15.1% in the same condition of

Experiment 1, and 14.1% in the Kanizsa-absent condition of Experiment 1, HSD = 5.5%, $p < 0.05$. The Kanizsa-absent condition of Experiment 2 did not reliably differ from either condition in Experiment 1 at Lag 1, averaging 19.3%.

Experiment 2 produced some notably different outcomes than Experiment 1, revealing effects of the presence of a Kanizsa figure. Both the ability to identify T2 and to integrate both targets improved at Lag 1. There also was no evidence for any effects at longer lags, which might be taken to point at an early locus in the perceptual/attentional system for the presently observed effects.

3.6. Experiment 3A

Experiment 2 provided evidence that the presence of a Kanizsa figure facilitates temporal integration compared with a stimulus configuration in which there was no clear Gestalt. Yet unanswered is the question of whether this facilitation is exclusive to the illusory contour brought about by the Kanizsa configuration or whether other Gestalt principles would have similar effects. Experiment 3 was designed to compare the Kanizsa effect against a condition in which another good Gestalt was implemented, using the same physical features.

3.6.1. Method

Experiment 3A was identical to Experiment 1 with the following exceptions.

3.6.1.1. Participants

Twenty-four (13 females) new students participated in the study (mean age 20.46 years, range 18-24).

3.6.1.2. Stimuli

In the Kanizsa condition, the stimuli were composed of cones placed around a circle, creating an illusory three-dimensional sphere, as shown in Fig. 3.1. In the other condition, the same cones were inverted 180°. This configuration has the properties of a good Gestalt; its features are not only similar and symmetrical but also display common fate; all the cones point to the center. Stimuli were 50 x 59 pixels (1.85° x 2.18° of visual angle) and the font of distractor stimuli was set to 60 pt. to match. The total area of the cones themselves covered 550 square pixels.

3.6.2. Results and discussion

T1 performance in the single target condition was 81% (SEM = 1.4%), whereas T1 accuracy in the two target condition was 58% (SEM = 1%; Table 3.1), and T2 accuracy was 56% (SEM = 1%). Only a significant main effect of Lag on T2|T1 accuracy was found, F(1, 27) = 16.95, MSE = 0.06, $p < 0.01$, η2 p = 0.42. Similar to Experiment 1 and 2, T2|T1 accuracy increased with increasing lag. T2|T1 accuracy was 70.7% at Lag 1, 87.6% at Lag 3, and 91.9% at Lag 8. Neither Kanizsa nor the interaction of Kanizsa and Lag had a significant effect on T2|T1 performance (Fig. 3.4 left panel).

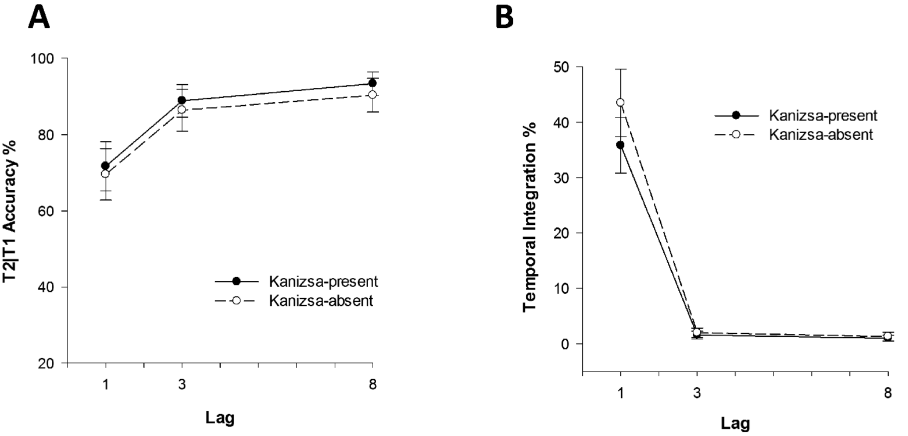


Fig. 3.4. Task performance of Experiment 3A as a function of lag. Error bars represent ±SEM. a T2|T1 performance in percent correct. b Percentage of temporal integration.

There were significant main effects of Lag and Kanizsa on integration frequency, F(1, 23) = 46.91, MSE = 0.10, $p < 0.01$, η2 p = 0.67, and F(1, 23) = 11.59, MSE = 0.002, $p < 0.01$, η2 p = 0.34. Integration was most frequent at Lag 1 (Fig. 3.4 right panel), averaging 39.6% compared with 1.8% at Lag 3 and 1.2% at Lag 8. Contrary to expectations, temporal integration frequency in trials with the illusory Kanizsa sphere was actually slightly but significantly less than in the inverted condition. A significant interaction effect of Kanizsa and Lag was furthermore found on temporal integration, F(1, 24) = 9.39, MSE = 0.004, $p < 0.01$, η2 p = 0.29. Temporal integration in the inverted condition was 43.5% at Lag 1, above the 35.8% observed in the Kanizsa sphere condition, HSD = 5%, $p < 0.05$.

3.7. Between experiment comparisons

Comparison of Experiments 2 and 3A revealed a two-way interaction of Kanizsa and Experiment, F(1, 47) = 10.58, MSE = 0.01, $p < 0.01$, η2 p = 0.18, as well as a three-way interaction of Kanizsa, Experiment and Lag, F(2, 73) = 23.14, MSE = 0.01, $p < 0.01$, η2 p = 0.33, on T2|T1 accuracy. T2|T1 accuracy in the Kanizsa-absent condition of Experiment 2 was 71.4% compared with 82.1% in Experiment 3A, HSD = 7.7%, $p < 0.05$. T2|T1 accuracy in the Kanizsa-absent condition of

Experiment 3A was greater than in the Kanizsa-absent condition of Experiment 2 at Lag 1, HSD = 11.9%, $p < 0.01$. In addition, T2|T1 accuracy in the Kanizsa-present condition of Experiment 3A was greater than in Experiment 2 at Lag 1, HSD = 11.9%, $p < 0.01$.

Interaction effects of Kanizsa and Experiment as well as Kanizsa, Experiment and Lag were found on temporal integration, $F(1, 47) = 26.31$, $MSE = 0.003$, $p < 0.01$, $\eta 2\ p = 0.36$; $F(1, 49) = 24.10$, $MSE = 0.005$, $p < 0.01$, $\eta 2\ p = 0.34$, respectively. Overall temporal integration in the Kanizsa-absent condition in Experiment 2 was 8.8% lower than in Experiment 3A, HSD = 4.8%, $p < 0.01$. The combined Gestalt effects in Experiment 3A seemed stronger than in Experiment 2, and as a result both the Kanizsa-present and -absent condition of Experiment 3A caused more temporal integration at Lag 1 than they did in the Kanizsa-present condition of Experiment 2, HSD = 4.6%, $p < 0.01$.

In summary, the outcomes of Experiment 3A suggested that although the presence of a Kanizsa figure does result in comparatively high integration rates, nevertheless it is not special by itself. The condition in which the Kanizsa figure was not apparent, but in which a good Gestalt was present, produced as much if not more temporal integration, clearly above the levels observed in Experiment 2.

3.8. Experiment 3B

Experiment 3B was conducted to generalize the finding of Experiment 3A that a non-Kanizsa Gestalt can be as effective as a Kanizsa figure. The motivation for conducting a further test was that in Experiment 3A the inverted, non-Kanizsa figure produced a particularly strong Gestalt, resembling an explosion pattern that might supersede its other properties. It is conceivable that the observed behavior resulted in part from the strength of this more subjective Gestalt. Therefore, in Experiment 3B, the cones were rotated further, so that apart from the feature similarity and symmetry present in all conditions, only the Gestalt cue of closure (marking a fairly continuous border along a rectangular center) was evident.

3.8.1. Method

Experiment 3B was identical to experiment 3 with the following changes.

3.8.1.1. Participants

Twenty-four (10 females) new students participated in the study (mean age 21.96 years, range 19-28).

3.8.1.2. Stimuli

The Kanizsa condition of Experiment 3A, comprising an illusory three-dimensional sphere, was again used. In the other condition, each big cone segment in each corner was rotated 90° and small cones were rotated 135° counter-clockwise as shown in Fig. 3.1. This rotation removed the Gestalt cue of common fate, thereby taking away the impression of an explosion pattern. The alignment of the cones along the edges of a rectangular center shape now introduced the Gestalt cue of closure, thereby unifying the corner segments within a single coherent figure without relying on an illusory contour.

3.8.2. Results and discussion

T1 performance averaged 83.5% (SEM = 0.5%) in the single target condition, and 59% (SEM = 0.5%) of T1 (Table 3.1) and 55% (SEM = 0.5%) of T2 in the two target conditions. There were significant main effects of Kanizsa and Lag on T2|T1 accuracy, F(1, 23) = 23.67, MSE = 0.02, $p < 0.01$, η2 p = 0.51, and F(1, 28) = 34.96, MSE = 0.06, $p < 0.01$, η2 p = 0.60. T2|T1 accuracy in the Kanizsa condition averaged 85.6%, whereas the rotated condition averaged 74.4%. T2|T1 accuracy at Lag 1 was 61.9% and increased to 86.1% at Lag 3 and to 92.1% at Lag 8 (Fig. 3.5 left panel).

Only Lag had a main effect on temporal integration, F(1, 23) = 45.17, MSE = 0.07, $p < 0.01$, η2 p = 0.66. Temporal integration frequency at Lag 1 was 33.9% and decreased to 2% at Lag 3 and to 0.9% at Lag 8. No effects of Kanizsa were apparent (F's < 2.11), confirming that with the presently used stimuli, the presence of a Kanizsa figure did not seem to further enhance target identification nor integration frequency compared with the non-Kanizsa Gestalt condition.

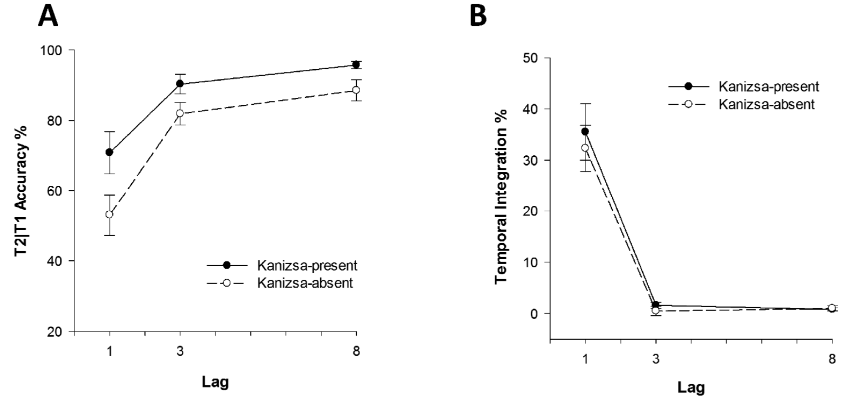


Fig. 3.5. Task performance of Experiment 3B as a function of lag. Error bars represent ±SEM. ***a.*** *T2|T1 performance in percent correct.* ***b.*** *Percentage of temporal integration.*

3.9. Between experiment comparisons

When comparing T2|T1 accuracy between Experiments 3A and 3B, an interaction of Kanizsa and Experiment on T2|T1 was found, $F(1, 46) = 7.18$, $MSE = 0.02$, $p < 0.01$, $\eta 2$ p = 0.14. T2|T1 accuracy in the Kanizsa-absent condition of Experiment 3A was higher than in the same condition of Experiment 3B, HSD = 7.8%, $p < 0.05$. Thus, the weaker Gestalt in the latter experiment caused T2|T1 accuracy to decrease.

A significant interaction of Kanizsa and Experiment, $F(1, 46) = 8.97$, $MSE = 0.002$, $p < 0.01$, $\eta 2$ p = 0.16, and also of Kanizsa, Lag, and Experiment, $F(1, 48) = 9.77$, $MSE = 0.002$, $p < 0.01$, $\eta 2$ p = 0.18, was found on temporal integration frequency. Post-hoc tests showed that overall temporal integration frequency in the rotated condition of Experiment 3B was significantly lower than in the same condition of Experiment 3A, presumably as a result of the weaker Gestalt in the former experiment, HSD = 3.8%, $p < 0.05$. At Lag 1, the removal of the explosion pattern from the Kanizsa-absent condition in Experiment 3B induced a significant decrease of 11.2% in temporal integration frequency from the level observed in the Kanizsa-absent (explosion-present) condition in Experiment 3A, HSD = 4.4%, $p < 0.01$.

Between experiment comparisons of Experiment 2 and 3B revealed a three-way interaction of Kanizsa, Experiment and Lag on T2|T1 accuracy, $F(1, 58) = 5.85$, $MSE = 0.02$, $p < 0.05$, $\eta 2$ p = 0.11. T2|T1 accuracy in either Kanizsa condition at Lag 1 in Experiment 3B was significantly higher than in Experiment 2, HSD = 6.5%, $p < 0.05$. At Lag 3, T2|T1 accuracy was significantly greater in Kanizsa-absent condition of Experiment 2 than the same condition of Experiment 3B.

With regard to temporal integration frequency, only an interaction effect of Kanizsa and Experiment was significant, $F(1, 47) = 4.90$, $MSE = 0.003$, $p < 0.05$, $\eta 2$ p = 0.09. Overall temporal integration in the Kanizsa-absent condition of Experiment 2 was 5.1% less than in the same condition of Experiment 3B, HSD = 2.6%, $p < 0.05$.

Experiment 3B thus continued to show relatively high T2 identification accuracy and integration rates. The specific appearance of a Kanizsa figure that unifies the corner segments of the stimuli did not seem critical; the Gestalt cue of closure was sufficient, even if the arrangement in Experiment 3A (the explosion pattern) proved to be slightly stronger still. Importantly, both configurations proved more effective than the non-Kanizsa inverted Pac-man stimuli of Experiment 2.

3.10. General discussion

The experiments in the present study revealed that the presence of a Kanizsa figure as well as other Gestalt cues influence performance in dual-target rapid serial visual presentation tasks. These effects seemed most consistent with regard to the frequency of temporal integration at Lag 1. Target identification performance was nevertheless also affected by the appearance of the stimuli, except in Experiment 3A. These effects were obtained at various lags and seemed related to masking effects between both targets and distractors, rather than to attentional processing.

In Experiments 1 and 3B, differences in target identification accuracy between Kanizsa and non-Kanizsa conditions were observed across all lags. By contrast, the differences in Experiment 2 were restricted to Lag 1. Both patterns can be accounted for by masking, under the assumption that the target stimuli were either primarily affected by the masking strength between targets and distractor letters, or between the targets themselves. In the former case, because targets appear amidst distractors at all lags, performance differences should not be sensitive to any particular lag, as was indeed observed in Experiments 1 and 3B. In these experiments, the evidence suggested that either the Kanizsa configuration based on corner segments or the non-Kanizsa configuration based on rotated cone segments were more strongly masked by the letter distractors. In Experiment 2, the Kanizsa-absent configuration of rotated Pac-man stimuli significantly impaired identification accuracy at Lag 1, suggesting that it was caused by the close temporal proximity of the targets themselves. Because this effect was observed on both T1 and T2 accuracy, an attentional explanation, in which the AB-sensitive T2 should presumably have been affected most, seemed less tenable.

It must be acknowledged that a unifying explanation of why some stimulus shapes seemed to be more prone to distractor- or target-related masking than others is currently lacking. A possible answer may be sought in the degree to which low-level visual processing stages are involved. Wang and colleagues (2012) showed that a Kanizsa triangle emerged to awareness faster from intraocular continuous flash suppression than a rotated Kanizsa figure, suggesting that some aspects of perceptual grouping of Kanizsa figures occur in early stages of processing. These early stages may be more involved in processing the Kanizsa figures used in Experiment 2, which elicited a strong illusory figure, than in processing the figures used in Experiment 1. Consequently, the Kanizsa figures of Experiment 1 might require the involvement of later stages of processing, which implies that ensuing masking stimuli may thereby have more impact. Because the main focus of the present paper was on Kanizsa and/or Gestalt effects on integration and attention, a full account of these seemingly unrelated masking effects falls outside its scope. Future research might more systematically consider the stimulus properties that affect masking strength and individual target detection in RSVP. It may be noted that in the context of the AB proper, masking effects have proven difficult to track in previous studies (Chun & Potter, 1995; Giesbrecht, Bischof, & Kingstone, 2003; McLaughlin, Shore, & Klein, 2001; Seiffert & Di Lollo, 1997; Visser, 2007; Ward, Duncan, & Shapiro, 1997).

The lack of an attentional effect is consistent with findings in the spatial domain by Li, Cave, and Wolfe (2008). In a series of visual search experiments, they found no evidence for an attentional benefit of Kanizsa grouping. The authors concluded that such grouping might not occur early enough for attention to benefit at a later stage of processing. This interpretation is at odds with other studies, however. For instance, in line with earlier studies (Davis & Driver, 1994), Conci et al. (2009) observed preattentive effects of bilateral illusory contour completion on patients suffering from visual extinction. Another event-related potential study by Conci et al. (2011) showed that the earliest components (P1, N1) already reflected differential amplitude as a function of global Kanizsa shape. It thus does not seem tenable to assume that delays in perceiving illusory contours by themselves caused the present lack of an attentional effect. In the context of RSVP, however, the delay between the successive parts of the Kanizsa figure may have been sufficient. The results suggested that the targets were individually selected in all cases and that no further attentional benefits were obtained from putting the Kanizsa parts together at a later stage, such as in working memory, which has previously been shown to make use of illusory shapes (Gao et al., 2015).

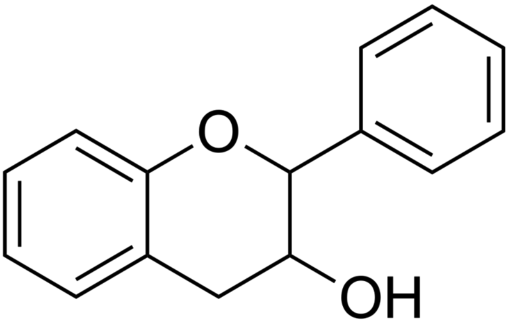
In contrast to the apparent lack of attention-related effects in the current study, the Gestalt properties of the targets did produce clear modulations of temporal integration frequency. Targets with good Gestalt properties were found to be more frequently integrated when presented in direct succession at Lag 1, which was in line with expectations. At the same time, the presence of a unifying illusory Kanizsa shape was not found to have an effect over and above that afforded by other Gestalt properties.

In all experiments, the individual target features were balanced and so by definition symmetrical along both horizontal and vertical axes, as well as similar in appearance. It could be argued that a baseline Gestalt level was present throughout compared with (hypothetical) fully non-configural stimuli. For the targets in Experiment 1, which replicated previous work (Akyürek et al., 2012), an arrangement of corner segments in which a rectangular Kanizsa shape might appear was not found to deviate from an inverted arrangement that removed the illusory contour: Both conditions resulted in comparatively modest integration rates. A direct comparison to Experiment 2, in which a traditional, strong Kanizsa inducing stimulus configuration (Pac-man circles) was used, showed that integration frequencies in Experiment 1 were similar to integration in the non-Kanizsa condition of Experiment 2. Thus, the corner segments in Experiment 1, even when oriented along a contour, did not seem to yield noticeable Gestalt benefits over other symmetrical arrangements.

The Kanizsa condition of Experiment 2 clearly induced increased integration at Lag 1, providing evidence that the spatial compatibility afforded by the illusory figure contributed to the temporal unification of the successively presented targets. However, the results of Experiments 3A and B cast doubt on the idea that the Kanizsa contour played a special role. In these experiments, an arrangement of cone segments designed to elicit an illusory Kanizsa sphere was contrasted with fully (180°) and partially rotated cones. Importantly, the rotated non-Kanizsa conditions did retain other good Gestalt properties (common fate or closure). These proved to be as effective as the Kanizsa condition, and all conditions produced integration rates comparable to the Kanizsa condition of Experiment 2. The results suggested that any of the presently tested good Gestalt properties were conducive to temporal integration. For temporal integration in RSVP, it can be concluded that perceptual grouping on the basis of illusory contours does not specifically enhance the process.

Chapter 4

The acute effects of cocoa flavanols on temporal and spatial attention



This chapter was previously published as:

Karabay, A., Saija, J. D., Field, D. T., & Akyürek, E. G. (2018). The acute effects of cocoa flavanols on temporal and spatial attention. *Psychopharmacology, 235*(5), 1497–1511. doi:10.1007/s00213-018-4861-4

Data and code available at osf.io/2snuy

4.1. Abstract

In this study, we investigated how the acute physiological effects of cocoa flavanols might result in specific cognitive changes, in particular in temporal and spatial attention. To this end, we pre-registered and implemented a randomized, double-blind, placebo and baseline-controlled crossover design. A sample of 48 university students participated in the study and each of them completed the experimental tasks in four conditions (baseline, placebo, low dose, and high-dose flavanol), administered in separate sessions with a 1-week washout interval. A rapid serial visual presentation task was used to test flavanol effects on temporal attention and integration, and a visual search task was similarly employed to investigate spatial attention. Results indicated that cocoa flavanols improved visual search efficiency, reflected by reduced reaction time. However, cocoa flavanols did not facilitate temporal attention nor integration, suggesting that flavanols may affect some aspects of attention, but not others. Potential underlying mechanisms are discussed.

Keywords: Cocoa flavanols; Rapid serial visual presentation; Visual search; Attention; Temporal integration

4.2. Introduction

Flavonoids such as flavones, flavanols, flavanones, and flavonols, which are a subclass of phenolic compounds, are found in various dietary sources. Flavanols, which are found in green tea, cocoa products, and red wine, are one of the 8000 polyphenols (Bravo, 1998). The effect of flavanols on human health has drawn considerable attention since flavanols containing products are consumed by many people in western countries on a daily basis. In this study, we focused on cocoa flavanols due to its higher flavanol content than other flavonoid-containing products such as tea and wine (Lee et al., 2003). Long-term studies revealed that sustained intake of cocoa flavanols (CF) decreases insulin resistance and provides benefits to cardiovascular health (Hooper et al., 2012). Moreover, the neuroprotective effects of CF in elderly people have been observed (Vauzour et al., 2008; Mastroiacovo et al., 2014). Various acute effects (i.e., occurring directly after consumption) on brain function have also been observed, on both physiological and cognitive measures (for a review on the cognitive effects of both acute and long-term use of cocoa flavanols, see Socci et al., 2017). In general, relative to acute physiological effects of cocoa flavanols administration (e.g., immediate cardiovascular effects), behavioral results have not been as unequivocal.

Starting with the latter, direct evidence for some (albeit limited) effects of CF consumption on cognitive functions was provided in a behavioral study conducted by Scholey et al. (2010), who found positive acute effects of CF consumption on cognitive task performance and mental fatigue. The standardized cognitive demand battery (CDB) test was used in a counterbalanced, double-blind, placebo-controlled design. Significant improvements as a result of acute CF consumption were found on the serial threes task, which involves counting backwards in threes from a random number between 800 and 999. No improvement was observed on the more difficult version of that task, the serial sevens. On a rapid visual information processing task, which required participants to monitor series of digits (at 100 digits per minute), and press a button when there are three odd digits in a row, no improvements in task accuracy due to CF were found either. However, significant improvements in reaction time were observed in their high dose CF condition (994 mg CF) in the third and fourth cycle of CDB (total of 6 cycles). Finally, mental fatigue was significantly improved after the consumption of a low dose of CF (520 mg), as measured by the scores on a visual analogue scale on which participants self-rated their mental fatigue.

Similarly, Massee et al. (2015) investigated acute and sub-chronic effects of CF on cognition using the CDB, in a randomized, double-blind, placebo-controlled, parallel design study. Significant improvements were found after consumption of CF (250 mg) in the serial sevens subtraction task, but only in the first cycle of the CDB (on a total of 3 cycles). Mental fatigue was also alleviated by CF in this study. Nevertheless, the CF effects on the CDB were not entirely consistent with those of

Scholey et al. (2010). Possible reasons could be methodological differences: for instance, in the amount of CF administered (250 mg as an experimental condition and 0 mg flavanol as a placebo vs. 500 mg as a low dose and 994 mg as a high dose), in the number of CDB cycles, and in the design (crossover vs. parallel).

Field et al. (2011) used dark chocolate (733 mg CF) and white chocolate (containing only a trace amount of CF) in a counterbalanced crossover design. They investigated effects of CF on visual and cognitive tasks. They found significant improvements of acute CF consumption on visual contrast sensitivity, and reaction time in motion integration, visual working memory, and choice reaction time tasks. However, since dark and white chocolate could be distinguished by participants, the study was not double-blind, and placebo effects might thus have contributed to the results. Furthermore, caffeine and theobromine were present in the dark chocolate while they were absent in the white chocolate. Hence, caffeine and theobromine levels in these two treatment conditions did not match, which could also explain the observed effects.

Grassi et al. (2016) investigated whether CF consumption counteracts effects of sleep deprivation on cognition, next to cardiovascular parameters. Participants visited the lab the night before each experimental session, and they either slept (sleep condition) or did not sleep (deprivation condition). Afterwards, participants consumed either flavanol-rich (520 mg) or flavanol poor (88.5 mg) dark chocolate. Each participant visited the lab four times so that a double-blind crossover design was realized. Ninety minutes after CF consumption, participants took psychomotor vigilance and 2- back tasks. For women, performance in the 2-back task did not decrease after sleep deprivation, when they had consumed flavanol-rich dark chocolate, while their performance did decrease when they consumed flavanol-poor dark chocolate. The study thus suggested that cocoa flavanols can restore working memory performance after sleep deprivation in women, implicating it might attenuate the effects of mental fatigue. Some caution must be exercised when interpreting these outcomes, however, because caffeine and theobromine levels were not matched between conditions (109 mg caffeine and 1200 mg theobromine in the flavanol-rich condition vs. 49 mg caffeine and 419 mg theobromine in the flavanol poor condition), which may have confounded the effect.

Finally, another study of both acute and chronic effects on cognitive performance and mood did not show effects of CF on cognitive performance, but only on mood: Pase et al. (2013) tested both acute and chronic effects of CF on cognitive performance in the so-called Cognitive Drug Research computerized assessment system, which is intended to test both attentional and (working) memory functions, using a randomized, placebo-controlled, double-blind, parallel groups design. Participants took the assessment 1, 2.5, and 4 h after they had consumed a CF-containing drink (0 mg, 250 mg, 500 mg CF), as a measure of acute effects, and they were tested again after 30 days of CF consumption. Neither of these tests provided any evidence for an effect of CF on cognitive performance. Self-reported mood was not affected after acute intake of CF either. However, after 30 days of daily CF intake, self-reported calmness and contentedness scores were significantly greater than the baseline scores in the high-flavanol condition. There was no improvement of CF on mood in low flavanol and placebo condition. It must nonetheless be noted that participants had a lunch break after the first testing session in this study, which means that post-prandial factors may potentially have contributed to the negative findings, particularly with regard to acute effects.

As alluded to, these various behavioral effects should obviously be rooted in transient physiological changes induced by CF consumption. The (potentially) beneficial physiological effects of CF depend in part on its ability to activate nitric oxide (NO) synthesis in vitro (Karim et al., 2000) and vivo (Fisher et al., 2003). NO has multiple biological functions, two of which could potentially explain the reports of enhanced cognition due to CF consumption—vasodilatory effects and neurotransmission. NO systems mediate vasodilation in blood vessels, including cerebral arteries, by stimulation of guanylate cyclase (Calver et al., 1992). Consistent with this, several studies have confirmed that consumption of CF influences cerebral blood flow (Francis et al., 2006). However, because vasodilation is not the only relevant biological role of NO, it cannot be assumed that the cerebral blood flow effect of CF consumption is solely responsible for effects of CF on measures of cognitive performance. Independently of its blood flow effects, CF also influences neuronal signaling pathways (Spencer, 2007). Specifically, NO acts as a neurotransmitter, although its behavior and effect is somewhat different to the classical neurotransmitters (Garthwaite, 1991), and this offers an alternative explanation of the cognitive effects of CF.

To date, there is no strong evidence in favor of either mechanism. In one study, Francis et al. (2006) showed increased cerebral blood flow 2 h after consumption of a flavanol-rich cocoa drink (containing 516 mg CF), compared to a low flavanol condition (39 mg CF) in a counterbalanced, double-blind, crossover design. However, even though increased blood flow in the brain should likely result in better cognitive performance overall, Francis et al. (2006) did not find behavioral evidence that CF increased performance in their task-switching test. This null result might have occurred because participants were trained to have less than 5% error rate in the task, so that performance might have been at ceiling. Alternatively, it might be that the cognitive functions involved in task-switching are less sensitive to CF effects.

In another study with a counterbalanced, double-blind, crossover design by Lamport et al. (2015), more specific physiological effects were found. The authors observed increased arterial spin labeling perfusion in two clusters, the anterior cingulate cortex and central opercular cortex of the left parietal lobe, after 2 h of 494 mg CF consumption in healthy elderly adults. Modulation of attention, executive functions, and error detection are some of the functions of the anterior cingulate cortex (for a review, see Bush et al., 2000). Furthermore, anterior cingulate cortex activation was previously found in attentional blink tasks (Marois et al., 2000), implicating temporal attention specifically. However, this remains indirect, as no behavioral task was performed in the study by Lamport et al. (2015).

Decroix et al. (2016) showed increased cerebral blood oxygenation due to CF intake by using a functional near-infrared light attenuation (NIR) setup in a double-blind, randomized, crossover design. The authors collected cerebral oxygenation levels three times, at baseline, and at 90 min and 140 min after baseline. At 90 min after baseline, a Stroop task was administered to investigate whether CF influences cerebral blood oxygenation levels and executive cognitive functions. Increased cerebral oxygenation as a result of 900 mg CF intake was observed, but there was no behavioral evidence that CF improved Stroop performance. Particularly because the Stroop task lasted for only 5 min, one account for the lack of a CF effect is that the task was too short to allow modulation of executive functions, as evidence from Grassi et al. (2016) suggested mental fatigue might be mediating CF effects on these functions.

Taken together, it seems fair to conclude that the evidence for acute effects remains mixed. It is conceivable that the mixed pattern of results has arisen because results from standardized test batteries do not always specifically target individual cognitive functions (such as only attention or working memory) in isolation. Also, methodological differences across studies, including CF dosage and administration (e.g., chocolate bar or beverage), and designs (crossover vs parallel), may explain some of the mixed results. Nevertheless, from the available evidence to date, such as the physiological data (Lamport et al., 2015), and the reaction time effects in the CDB (Scholey et al., 2010), we speculate that CF might particularly affect attention. The present study sought to provide a decisive test of this possibility, firstly by employing a randomized, counterbalanced, double-blind, placebo- and baseline-controlled, crossover design, which was also pre-registered; its full specification, including analysis plan and hypotheses, were published online on the Open Science Framework website (www.osf.io) in advance. Secondly, we also used a novel approach to specifically target attentional deployment in both time and space: we chose experimental tasks that are commonly used by attention researchers, rather than tasks from cognitive test batteries. Doing so allowed for a more focused examination of attention in isolation, rather than as one part of a multidimensional array of cognitive functions that participants are typically required to perform in test batteries.

To investigate whether CF influences attention in time and space specifically, a hybrid attentional blink/temporal integration task and a visual search task were implemented in the present study. The first task was a rapid serial visual presentation (RSVP) task. In a classical RSVP task, distractors and targets are successively shown on the same central location on a screen in a very short time period (~ 10 visual items per second), and the task is to identify and report target items among distractor items. Typically, two targets are inserted in the stimulus stream, and when the second target follows within 200–500 ms of the first target (Raymond et al., 1992), its identification is difficult, and this is known as the attentional blink (AB) phenomenon. Although various factors can influence second target identification accuracy in RSVP (for a review see Dux & Marois, 2009), the AB is still generally regarded as closely tracking the deployment of attention across time. Furthermore, in our hybrid task, target integration, which is the perception of a combined, integrated compound target out of two successively presented targets, could be assessed separately. Integration is one way to avoid the AB (Akyürek et al., 2012; Bowman & Wyble, 2007). Hence, this task can also shed light on temporal integration mechanisms that may modulate temporal attention, thereby providing a more sensitive measure of possible CF effects. Visual search (VS) constituted the second task, which is used to investigate the accuracy and efficiency of the deployment of spatial attention (for a review, see Wolfe, 1998). The task is to detect whether a single target item was present or absent in a visual array consisting of a number of items. The difficulty of visual search, which is primarily reflected in reaction times to the search array, depends on the ease of discrimination of a target element amidst distractors, and the number of elements that must be inspected—except in the case where the target is very different from the distractors, in which case there is no effect of the number of elements in the visual display, commonly known as pop-out search. In our task, search difficulty was manipulated by introducing a second salient item in the search arrays, which either matched or did not match the relevant target features (cf. Akyürek & Schubö, 2011).

Taken together, two main questions were addressed in this study: (I) Whether acute CF consumption facilitates temporal attention and/or integration and (II) Whether acute CF consumption enhances spatial attention in terms of accuracy and/ or efficiency (i.e., reaction time).

4.3. Methods

4.3.1. Participants

Forty-eight (24 female) healthy non-smoking volunteers participated in the study (mean age = 22.15 years, range = 18–29, SEM = .01). None of them were previously diagnosed with any vascular disease, with a health disorder affecting metabolism, or with neurological or psychiatric disorders. They were not following a medically restricted diet or taking vitamin supplements, they were not pregnant or breastfeeding, and they had a body weight between 55 and 90 kg. All subjects had best-corrected visual acuity of 20/20 (Snellen) at a test distance of 35 cm and were able to pass the Ishihara color vision test. The mean height of male participants was 174.5 cm (range = 160–198 cm, SEM = 1.67), and the mean height of females was 165.6 cm (range = 153–187 cm, SEM = 1.50). The mean body weight of male participants was 72.7 kg (range = 57–90 kg, SEM = 1.90), and the mean female weight was 61.8 kg (range = 55–78 kg, SEM = 1.46). Written informed consent was obtained prior to participation and participants received 25 euros remuneration. The study was approved by the ethical committee of the Psychology Department of the University of Groningen (approval number ppo-014-227) and was conducted in accordance with the Declaration of Helsinki (2008).

4.3.2. General procedure

Participants visited the lab on four separate days, with a washout period of at least 1 week in-between to ensure any effects of the previous session had dissipated. Each session started at a fixed time: At 10:00, 11:00, 14:00, or 15:00. Subjects visited the lab at the same time and day of the week for each of their sessions, to avoid introducing differential diurnal effects. On the day of, and the day before each lab visit, the participants were asked to abstain from consuming products that contain caffeine, alcohol, high concentrations of flavonoids or theobromine (cf. Field et al., 2011), or herb supplements. A list with products that contain these prohibited components was given to the participants, and the importance of compliance was stressed before the first visit and at each visit. The list contained products such as coffee, tea, alcoholic beverages, and dark (high cocoa content) chocolate, as well as herbal teas and supplements (cf. Sokolov et al., 2013). Participants were asked whether they complied at each visit, while making it clear that although their data would have to be discarded in case of non-compliance, they would still receive financial reimbursement as agreed (promoting self-report honesty). A researcher that was not otherwise involved in the administration of the experiment served the drinks containing the experimental products (or not, see below) to the participants 2 h prior to the experiment. The delay between consumption and experiment was chosen to allow proper CF uptake by the body (Francis et al., 2006; Lamport et al., 2015). Across sessions, each participant consumed all four drinks in a randomly assigned order, which was counterbalanced between subjects. Between consumption and test, participants were invited to wait in the library, and asked not to consume anything, except for one additional glass of water, if desired. Participants were not aware of the type of drinks they consumed (see below), except for the baseline condition, since its visual appearance and taste did not mask the fact that it was a mixture of water and sugar. Another researcher, who was not aware of the experimental product that the participants had consumed, handled subsequent data collection in the lab. Participants took the visual acuity test and the color blindness test at the first session, where their weight and height were also measured. Each participant was seated approximately 60 cm away from the screen in a dimly lit, sound and light attenuated testing cabin. Participants completed two experimental tasks which were counterbalanced across participants: A dual-target rapid serial visual presentation task, and a dual-singleton visual search task.

4.3.3. Apparatus

The experimental tasks were presented on a 22-inch CRT monitor (Iiyama MA203DT) with a refresh rate of 100 Hz, at 16-bit color depth. Experimental tasks were programmed in E-prime 2.0 Professional (Psychology Software Tools) and executed under the Windows 7 operating system. Responses were collected with a standard USB keyboard.

4.3.4. Experimental product

High-flavanol Acticoa ™ cocoa powder, containing 8.3 g flavanols/100 g, as well as alkalized cocoa powder that contained no flavanols, were provided free of charge by Barry Callebaut. No other support, including sponsoring or financing of any kind was given, and the company had no other involvement in the study. Both types of cocoa powder were otherwise closely matched, including on levels of caffeine and theobromine, which both could potentially reduce fatigue and enhance alertness. The most notable difference was that the alkalized powder necessarily contained more potassium, 4790 mg K/100 g, compared to 1500 mg K/100 g for the high-flavanol powder. The cocoa was served as drink with 300 ml hot water and 20 g sugar to enhance palatability. There were four conditions: baseline, placebo, low dose, and high dose. Neither baseline nor placebo condition contained any CF. The baseline condition consisted of 20 g sugar dissolved in warm water, while the placebo condition additionally included 11 g alkalized cocoa powder. The low and high CF doses consisted of mixed cocoa powder so that the drink contained 374 mg CF in the low-dose condition and 747 mg CF in high-dose condition. To this end, the low-dose condition included 4.5 g high-flavanol cocoa powder, and 6.5 g alkalized cocoa powder, while the high-dose condition contained 9 g high-flavanol cocoa powder and 2 g alkalized powder. Further details of the composition of the cocoa powders are listed in Table 4.1.

Table. 4.1. Nutritional composition of the study treatments

	Baseline	Placebo	Low Dose	High Dose
Alkalized cocoa powder (gr)	0	11	6.5	2
Flavanol (mg)	0	0	0	0
Energy (kcal)	0	33.5	19.8	6.1
Protein (mg)	0	2442	1443	444
Fat (mg)	0	1210	715	220
Caffeine (mg)	0	22	13	4
Theobromine (mg)	0	231	136.5	42
High flavanol cocoa powder (gr)	0	0	4.5	9
Flavanol (mg)	0	0	373.5	747
Energy (kcal)	0	0	15.5	31.1
Protein (mg)	0	0	1008	2016
Fat (mg)	0	0	630	1260
Caffeine (mg)	0	0	9	18
Theobromine (mg)	0	0	94.5	189
Sugar (gr)	20	20	20	20
Hot Water (ml)	300	300	300	300

4.3.5. Experimental tasks

4.3.5.1. Attentional blink/integration task (RSVP)

An RSVP composed of distractors and targets, in which temporally segregated targets could also be temporally integrated into a single percept, was shown in the center of the screen on a light gray background (RGB 192, 192, 192). On each trial, participants were to focus on the continuous stream of visual items, and identify the first target (T1) as well as the second target (T2), if present, amidst the distractors. Screen resolution was set to 1024 × 768 pixels. Distractor stimuli were chosen from the alphabet without replacement on each trial and presented in black 52 pt. bold Courier New Font. Target stimuli consisted of 1–4 black corner segments of a square (see the Appendix 3 for a set of all possible targets). To avoid feature overlap, T2 never comprised a corner segment that was used for T1 in the same trial. Target stimuli extended to an area of 60 by 60 pixels (2.22° by 2.22° of visual angle) and were shown in the center of the screen. The width of each corner segment was 7 pixels (.26° of visual angle) and the length was 23 pixels (.85° of visual angle) so that the area of each corner segment was 273 pixels square. The gap between adjacent corner segments was 8 pixels (.3° of visual angle).

The task started with 20 practice trials, which were omitted from the analysis. Two identical experimental blocks followed, and each block consisted of

160 trials which were randomized within each block. Participants were explicitly offered a rest break between blocks. The experiment was self-paced, and participants were asked to press ENTER to start each trial. As shown in Fig. 4.1a, after 100 ms of pressing ENTER, a fixation cross (+) in the same font and size as the distractor stimuli appeared in the middle of the screen for 200 ms. An RSVP accommodating 18 items started after the cross. Each item was shown for 70 ms with a blank interval of 10 ms in between. T1 was shown as the fifth or seventh item in the RSVP, which was randomized and equally distributed; 75% of the trials contained two targets while the rest only contained one target in the stream. Thus, in 25% of the trials, T2 followed T1 immediately (lag 1), as the third item (lag 3) or as the eighth item (lag 8).

At the end of each trial, two successive response prompts asked participants to enter T1 and T2. Participants were able to report the corner segments of both targets individually by pressing related keyboard buttons (1, 2, 4, and 5), followed by ENTER. Participants were also able to enter only one target by pressing the related keyboard buttons for one prompt and leaving the other response prompt empty by only pressing ENTER. Furthermore, participants were allowed to leave both response prompts empty, but were encouraged to guess at the target identities if they were merely uncertain. The total duration of the RSVP task was approximately 30 min, depending on individual response speed.

4.3.5.2. Visual search task (VS)

The search display was composed of 21 lines of 30 × 5 pixels (1.42° by .24° of visual angle) on a white background at a screen resolution of 800 × 600 pixels. Participants were asked to find a color-defined target stimulus within this search display. Lines were arranged in a centered circular array, and the distance between adjacent lines was 50 pixels (2.37° of visual angle). Nineteen lines in the array were oriented vertically and black, one line was always a non-target stimulus and the other remaining line was either a target stimulus or another non-target stimulus. The target stimulus was an iso-luminant blue, green, or red vertical line. Non-target stimuli were either 45° clockwise/counterclockwise rotated lines or colored vertical lines that did not match the current target color. The two (non-)target stimuli were placed randomly on the search display, but one always appeared in the right visual field while the other appeared in the left visual field.

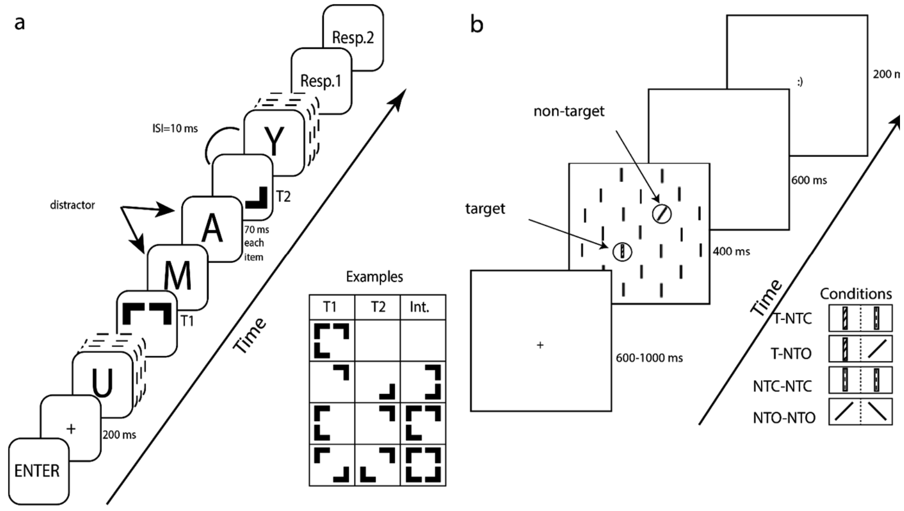


Fig. 4.1. ***a.*** *An illustration of the procedure of the attentional blink/ integration task at lag 3 where there are two distractors between targets. Letters are distractors, and targets appear among distractors in rapid succession. Resp. refers to response prompt. Example stimuli are shown in the box on the right bottom corner of the left panel.* ***b.*** *An illustration of the procedure of the VS task. Task conditions are illustrated in the lower right corner. T indicates a (color) target, NTO refers to an orientation nontarget and NTC means a color non-target. The color of non-targets was always different from the color of the target stimulus. Stimuli always consisted of solid lines. Diagonal line fills indicate color, and dashed line fills represent different colors of the non-target items*

There were two experimental conditions in the task: target presence and non-target features. There were two levels of target presence, target present or target absent, and two levels of non-target features, line orientation or line color. Thus, in the target-present condition, search displays contained one (color) target, and one task-irrelevant color or orientation non-target stimulus. In the target-absent condition, there were two non-target stimuli that were either both colored or both oriented.

There were two identical blocks in the experiment and each block included three sub-blocks, whose order was randomized within subjects. The target color was different on each sub-block of 96 trials, being green, red, or blue, and the participants were instructed accordingly. Each trial started with a fixation cross with a random duration between 600 and 1000 ms. After the fixation cross, the search array appeared on the screen for 400 ms, which was followed by a blank screen for 600 ms. Participants reported whether a target stimulus was shown or not by pressing 1 (target present) or 2 (target absent) on the numeric keypad of a standard keyboard. Participants were asked to respond as fast as possible and their response time was restricted to 1000 ms in total. A happy smiley appeared for 200 ms as a feedback for correct responses, and an unhappy smiley for late and incorrect ones (Fig. 4.1b), after which the next trial commenced. The duration of the VS task was approximately 25 min.

4.3.6. Design and analysis

As indicated, a randomized, double-blind, baseline- and placebo-controlled, counterbalanced, crossover design was used. Each participant was tested under four conditions of CF: baseline, placebo, low dose (374 mg CF), and high dose (747 mg CF), separated by a 7-day washout period. Treatment order was randomized and counterbalanced between participants to prevent any differential learning effects from influencing the results.

A 4 (CF) × 3 (lag) design was used for the AB/integration task.2 In order to investigate the attentional blink, the mean percentage of T2 identification in the trials in which T1 was identified correctly (T2|T1) was calculated, as is the common practice (e.g., Chun and Potter 1995). To measure temporal integration, trials in which T1 and T2 were reported as a single, integrated percept in one of the response prompts were counted, with the additional requirement that the other response prompt was left empty. Furthermore, lag-specific analyses of the effect of CF on both T2|T1 accuracy and temporal integration were planned a priori, as both attentional blink and temporal integration are known to affect specific lags only. Thus, for temporal integration, for instance, Lag 1 was focused on, since temporal integration of targets in RSVP occurs mostly there (e.g., Karabay and Akyürek 2017). Participants with an overall T1 or T2 accuracy below 25% were considered unable to perform the task well in general and omitted from the RSVP data analysis. Four participants were consequently excluded due to low performance; one participant was excluded since his data file was empty meaning either there was a problem with response input or the task was not completed correctly. The outcomes of the experiment did not change without these exclusions.

A 4 (CF) × 2 (target presence) × 2 (non-target features) repeated measures ANOVA was used to analyze performance in the VS task for both accuracy and reaction times. Reaction times were averaged from correct trials only, and reaction times less than 100 ms were excluded from the analysis since they were considered as a random or anticipatory response. None of the participants were excluded from the analysis of the VS task.

SPSS 23.0 was used for the repeated measures ANOVA analyses in both the AB/integration task and VS task, and Greenhouse-Geisser correction was applied when appropriate. Tukey (HSD) was used for pair-wise comparisons to characterize interaction effects. A detailed overview of all means underlying the analyses in both tasks, as well as a correlation matrix between RT and accuracy in the VS task, can be found in the Appendix 3.

4.3.7. Preregistration and data availability

In the interest of scientific transparency the present study was fully pre-registered on the Open Science Framework with the identifier zfg85 (https://osf.io/zfg85; https://doi.org/10.17605/ OSF.IO/ZFG85). This public pre-registration comprised the design, hypotheses, analysis approach, randomizations, and the experimental programs (including instructions). The data collected for this study, as well as the analysis scripts that were used, have since been uploaded with the identifier 2snuy (https://osf.io/2snuy; https://doi.org/10.17605/OSF.IO/2SNUY).

4.4. Results and discussion

4.4.1. AB task

T1 accuracy averaged 76.62% (SEM = 1.49%) in one-target trials in the AB task. Mean T1 accuracy across all conditions in two-target trials was 69.08% (SEM = 2.38%), and overall T2 accuracy was 64.58% (SEM = 2.64%). A significant main effect was found for lag on T2|T1 accuracy, F(1, 49) = 50.94, MSE = .12, $p < .01$, $\eta 2$ p = .55. T2|T1 accuracy averaged 62.3% at Lag 1, 79.2% at Lag 3, and 90.4% at Lag 8. Neither a main effect of CF nor an interaction effect of CF and lag on T2|T1 accuracy were found, F(2, 90) = 1.04, MSE = .05, p = .36, $\eta 2$ p = .02, and F(4, 160) = 2.41, MSE = .01, p = .054, $\eta 2$ p = .05, respectively. Lag-specific follow-up analyses showed that the effect of CF on T2|T1 accuracy was not significant, neither at Lag 1 nor at Lag 3, F(3, 112) = 1.12, MSE = .03, p = .35, $\eta 2$ p = .03; F(2, 80) = 1.03, MSE = .02, p = .36, $\eta 2$ p = .02. T2|T1 accuracy, therefore, varied by lag as expected, but was independent of CF condition (Fig. 4.2).

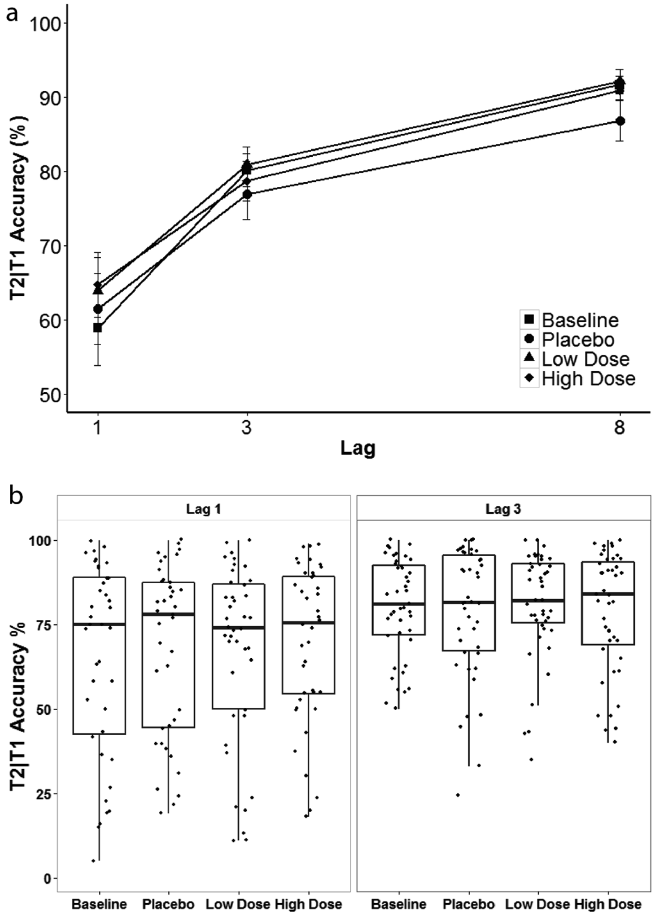


Fig. 4.2. ***a****. Average T2|T1 (T2 accuracy given that T1 was identified correctly) in percent correct. Error bars represent ± SEM.* ***b****. Whisker plot of lagspecific T2|T1 performance. Dots represent individual data points*

Lag had a significant main effect on temporal integration, F(1, 43) = 46.67, MSE = .06, p < .01, η2 p = .53. Temporal integration averaged 16.9% at Lag 1, 1.4% at Lag 3, and 0.4% at Lag 8, in line with the expectation that integration should only occur at the shortest lag. Both the main effect of CF and the interaction effect of CF and lag were not significant, F(2, 103) = 1.18, MSE = .00, p = .32, η2 p = .03, and F(3, 119) = .84, MSE = .00, p = .47, η2 p = .02, respectively. Further lag-specific analysis confirmed previous findings. The effect of CF on temporal integration at Lag 1 was not significant, F(3, 109) = .95, MSE = .01, p = .41, η2 p = .02 (Fig. 4.3). These analyses thus showed that although integration occurred at Lag 1 as expected, there was no evidence that CF further influenced temporal integration.

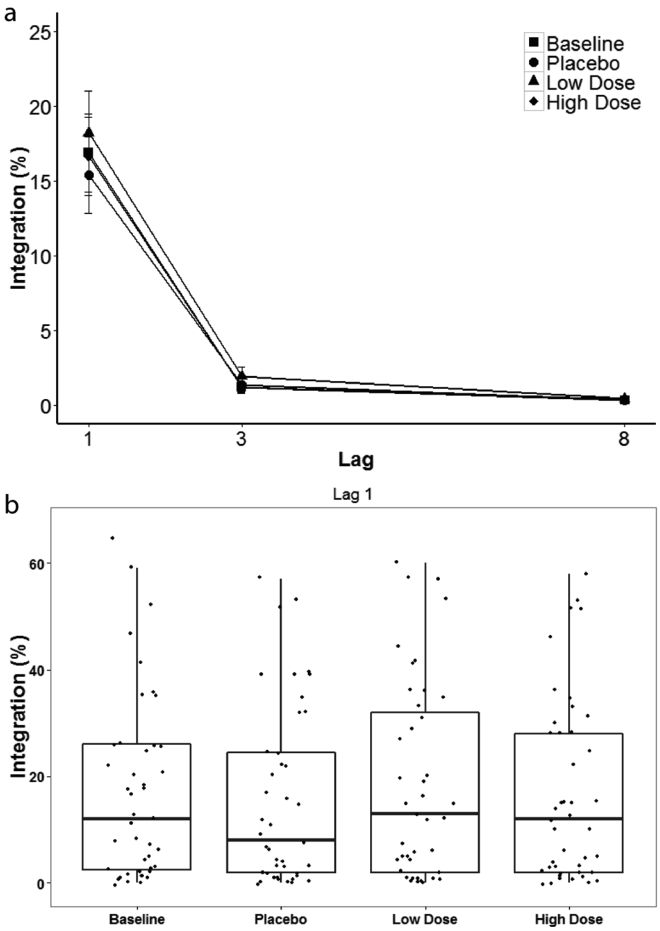


Fig. 4.3. ***a***. *Frequency of temporal integration (%) in the AB task. Error bars represent ± SEM.* ***b***. *Whisker plot of temporal integration at Lag 1. Dots represent individual data points*

4.4.2. VS task

Three-way repeated measures ANOVA results revealed that accuracy in the VS task was significantly dependent on target presence, F(1, 47) = 27.36, MSE = .00, p < .01, η2 p = .37, as well as non-target features, F(1, 47) = 50.97, MSE = .00, p < .01, η2 p = .52. Mean accuracy was 94.9% in the target-present condition, and 96.1% in the target-absent condition. Task accuracy averaged 94.8% in the color non-target condition, and 96.3% in the orientation non-target condition. A significant interaction existed for target presence and non-target features, F(1, 47) = 8.58, MSE = .00, p = .01, η2 p = .15. Further post hoc analysis showed that accuracy in the target-absent condition, orientation non-targets resulted in significantly higher accuracy than color non-targets [t = 2.9, p < .05]. In the target-absent condition, accuracy in the orientation non-targets condition was also reliably higher than in both non-target conditions of the target-present condition [t1 = 4.3, t2 = 3.2, p < .01]. There was no evidence that CF, F(3, 125) = 1.69, MSE = .00, p = .18, η2 p = .04; the interaction of CF and target presence, F(3, 119) = .29, MSE = .00, p = .80, η2 p = .01; the interaction of CF and non-target features, F(3, 123) = 1.09, MSE = .00, p = .35, η2 p = .02; or the three-way interaction of CF, target presence and non-target features, F(3, 133) = .38, MSE = .00, p = .76, η2 p = .01, had a significant influence on VS accuracy. Accuracy in the VS task was thus dependent on the stimulus manipulations, but independent of the CF conditions (Fig. 4.4).

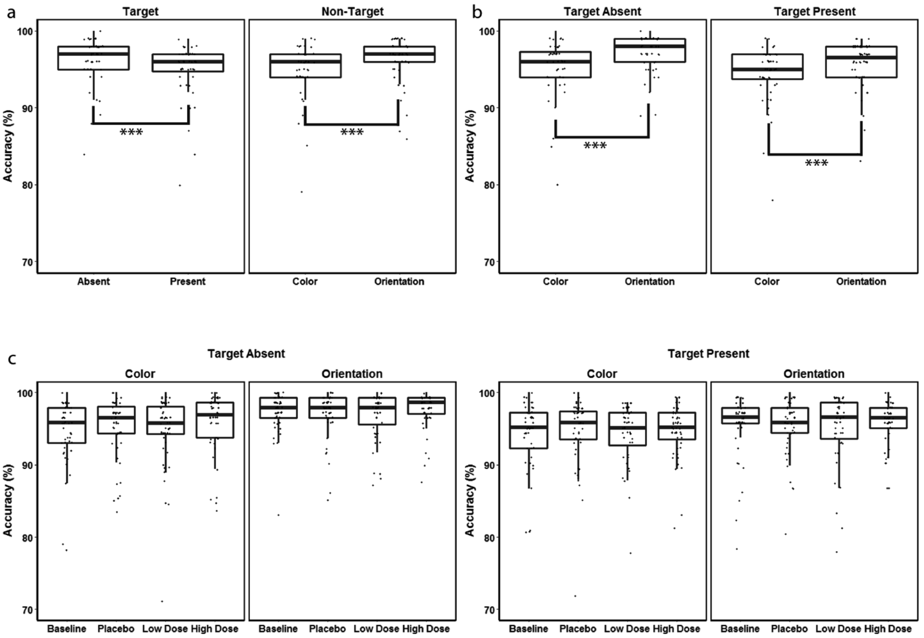


Fig. 4.4. Whisker plots of the accuracy in the VS task (% correct), in which dots indicate individual data points. Significant differences are indicated with asterisks (indicates p < .05; ** indicates p < .01, and *** indicates p < .001).* ***a.*** *The left panel shows the main effect of target presence, the right panel shows the main effect of non-target features.* ***b.*** *Interaction effect of target presence and non-target features.* ***c.*** *Interaction effect of target presence, non-target features and CF.*

The ANOVA on reaction times in the VS task showed significant main effects of target presence, F(1, 47) = 21.09, MSE = 1752.92, p < .01, η2 p = .31, and non-target features, F(1, 47) = 176.94, MSE = 256.14, p < .01, η2 p = .79. The interaction of target presence and non-target features was also reliable, F(1, 47) = 80.88, MSE = 138.27, p < .01, η2 p = .63. Mean RT was 334 ms in the target-present condition and 348 ms in the target-absent condition. RT averaged 348 ms in the color non-target condition, and 333 ms in the orientation condition (see Fig. 4.5). Pair-wise comparisons of the interaction effect of target presence and non-target features showed that RT in the orientation non-target trials in the target-present condition was lower than in the color non-target trials in both target-present [t = 2.6, p < .05] and absent conditions [t = 10.2, p < .01]. Furthermore, RT in the color non-target trials in the target-absent condition was significantly higher than in the orientation non-target trials of the same condition [t = 7.8, p < .01], as well as higher than in the color non-target trials of the target-present condition [t = 7.3, p < .01]. The shortest RT was observed in the orientation non-target trials in the target-present condition, and the longest RT was observed in the color non-target trials in the target-present condition.

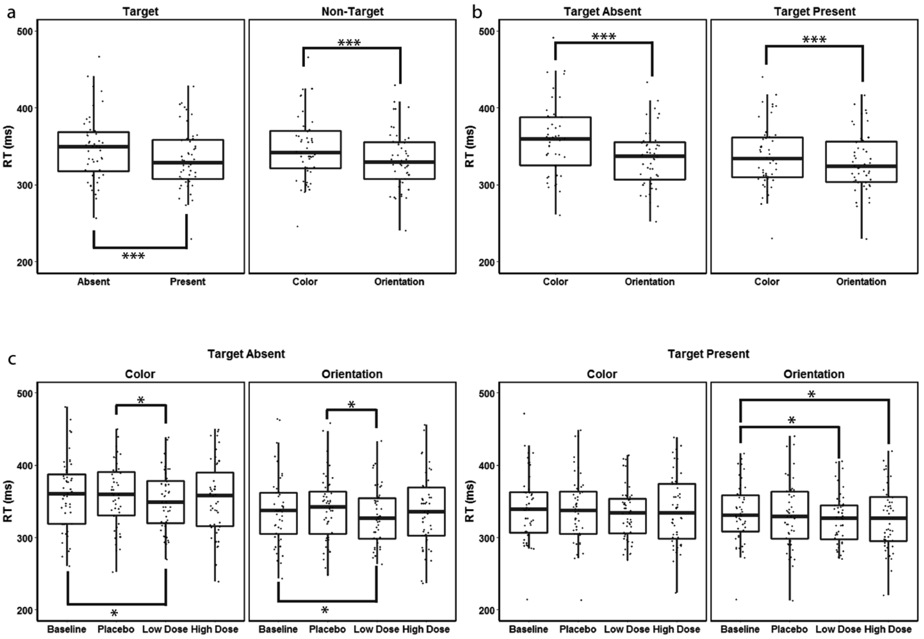


Fig. 4.5. Whisker plots of RT (ms) in the VS task, where dots indicate individual data points. Significant differences are indicated with asterisks (indicates p < .05; ** indicates p < .01, and *** indicates p < .001).* ***a.*** *The left panel shows the main effect of target presence, the right panel shows the main effect of non-target features.* ***b.*** *Interaction effect of target presence and non-target features.* ***c.*** *Interaction effect of target presence, non-target features and CF.*

The main effect of CF on RT, F(3, 127) = 2.09, MSE = 1965.02, p= .11, η2 p = .04, its interaction with target presence, F(3, 139) = 1.32, MSE = 206.06, p=.27, η2 p = .03, as well as its interaction with non-target features, F(3, 133) = .02, MSE = 54.41,p= .99, η2 p = .00, were all insignificant. Crucially, a significant interaction effect of CF, target presence and non-target features, was found, F(3, 134) = 4.35, MSE = 45.63, $p < .01$, $\eta 2$ p = .09. RTs in the low CF dose condition in both the color and orientation non-target trials of the target-absent condition were significantly lower than in the baseline and placebo CF condition [t1 = 2.2, t2 = 2.3, t3 = 2.0, t4 = 2.0, $p < .05$, respectively]. Moreover, RTs in the low and high CF dose condition in the orientation non-target trials in the target-present condition were lower than in the baseline condition [t1 = 2.45, t2 = 2.85, $p < .05$] (see Fig. 4.5).

4.5. General discussion

We investigated acute CF effects on temporal and spatial attention in young adults with a double-blind, randomized, counterbalanced, placebo- and baseline-controlled, crossover design. Our study revealed two main outcomes, namely that CF does not influence temporal attention, but that CF does decrease RT in visual search with medium effect size, and without losing accuracy, suggesting that search efficiency was improved. Faster reaction times were observed in the low dose CF condition than in the baseline and placebo conditions when the target was absent from the search array. A similar effect was observed in the low- and high-dose conditions, compared to the baseline condition, when the target was present and the non-target was a tilted line (i.e., not defined in the task-relevant feature dimension).

Even though anterior cingulate cortex activation was previously found in attentional blink tasks (Marois et al., 2000), and in which increased arterial spin labeling perfusion in resting state after CF consumption was observed (Lamport et al., 2015), the present study produced no evidence that T2|T1 accuracy or temporal integration were affected by CF. Since the anterior cingulate cortex has other functions, apart from attentional control, such as executive functions and error detection, it is possible that these cognitive functions rather than temporal attention may be more affected by CF consumption. The present findings are also compatible with previous measures of sustained attention, as found in the cognitive drug research task battery (Pase et al., 2013). Similarly, insofar as the Stroop task can be taken to reflect selective attention, previous research has not found evidence for CF effects therein either (Massee et al., 2015; Decroix et al., 2016). It must be noted, however, that factors other than attention may underlie the Stroop effect (MacLeod, 1991).

CF consumption also did not facilitate VS accuracy. A ceiling effect may have occurred, because mean accuracy was above 94% in all conditions, so that there may have been no room left for CF to enhance VS accuracy. Such performance is not atypical in spatial attention tasks, and for that reason, reaction time is typically regarded as a more sensitive and indicative measure of performance than accuracy. Critically, in the current task, RT was clearly influenced by CF consumption, suggesting that the efficiency of spatial attention was improved. It was found that both low and high doses of CF consumption resulted in shorter RTs than observed in the placebo and/or baseline conditions. It is important to note here that this result cannot be attributed to a general, possibly non-cognitive speeding of responses, or retinal effects (e.g., improved contrast sensitivity): The effect of CF consumption was only expressed through an interaction with both the variables that affected search difficulty (target presence and non-target features), pointing toward a cognitive locus. Specifically, faster RTs were observed when the target was absent in the visual array, regardless of non-target features. Furthermore, when the target was present and non-target items did not share the same feature type (color vs orientation), faster RTs were observed after CF consumption.

Previous behavioral studies have also found reaction time effects of CF on various tasks, such as rapid visual information processing tasks (Scholey et al., 2010), motion integration time threshold, and choice reaction time tasks (Field et al., 2011). At the same time, and similar to the present study, rapid serial visual information accuracy was not affected by CF consumption in these studies. The current outcomes with regard to RT speeding in visual search suggest that improved efficiency of spatial attention may (in part) have driven such previously observed effects.

Alternatively, another possible explanation for the observed difference between temporal and spatial attention might be based on differences between the RSVP and VS tasks themselves, in particular the possibility to make saccadic eye movements. Stimuli were shown in the center of screen in sequential order in the RSVP task, minimizing saccadic eye movements and eye blinks (Benedetto et al., 2015). In the VS task, the target stimulus was shown on either the right or left side of the screen for 400 ms, allowing two or three saccadic eye movements on each trial in the VS task. Therefore, acute CF effects in the visual search task may also have been facilitated faster saccades. If CF influences saccadic eye movements, such effects should be seen in other tasks allowing saccades. Significant acute CF effects on tasks allowing saccades were observed in one visual spatial working memory task (Field et al., 2011). However, another study that also used a spatial working memory task (Massee et al., 2015) showed no effect of CF. It has to be noted that fundamental differences in research designs of these two studies—within subject vs between-subject design, 773 mg CF vs 250 mg CF—may hinder the comparison. Since the current study did not directly measure saccadic eye movements, and in view of the mixed evidence to date with regard to a possible role for eye movements, this remains an open question for now.

4.5.1. Physiological mechanisms

Although the current study was strictly behavioral, its outcomes may also shed some light on possible underlying physiological mechanisms. From previous work, it is known that acute effects of CF may be caused by two effects related to NO synthesis: on vasodilation (blood flow) and neurotransmission (Calver et al., 1992; Garthwaite, 1991; Spencer, 2007). In general, if vasodilation and blood flow changes in the brain are the causal factor, then beneficial effects of CF should not depend on the type of cognitive process measured, although they might occur selectively in lengthy and fatiguing testing situations where supplies of glucose and other metabolites carried in the blood could become a determinant of performance. The same argument applies to one of the other proposed mechanisms by which flavonoids might improve cognitive function—improved blood glucose regulation (Bell et al., 2015). On the other hand, if an influence on neuronal signaling via NO or some other route is the cause then CF could influence information processing itself. This hypothesis predicts an alteration in the balance between different neural and cognitive processes underlying cognition; in terms of cognitive tests, the effects of CF should be selective rather than general. Because the current outcomes show that CF has specific rather than general cognitive effects, it seems more likely that they are due to acute changes in neurotransmission, rather than in blood flow.

4.6. Conclusion

The outcomes of the present study suggest that in a sample of young, healthy adults, the acute effects of CF consumption do not include modulation of temporal attention, but also that CF consumption does enhance the efficiency of spatial attention. There is thus evidence to conclude that although CF consumption may not generally enhance cognitive processes (cf. Pase et al., 2013), it can produce facilitation of specific cognitive functions.

Acknowledgments

The authors are grateful to Alana Wulff and Ciaran McAllister for their help with data acquisition.

Chapter 5

General Discussion

In this dissertation, we investigated whether temporal target identification and temporal integration have similar underlying cognitive mechanisms. In order to do that, as a first step we manipulated low-level stimulus features (chapter 2). The main question was how featural (color) and/or non-featural (contrast) changes in successive target pairs in RSVP influence temporal attention and integration. As a second step, the effects of more complex stimuli on target identification and integration were investigated by manipulating the Gestalt properties of the stimuli (chapter 3). Lastly, we manipulated the mental state of participants and investigated whether temporal integration and attention are influenced by acute consumption of cocoa flavanols in a similar direction, adding an extra measurement of spatial attention as well (chapter 4). In this final section of the dissertation, an overview of the empirical chapters is provided, and the relevant theories are evaluated with regard to our findings.

5.1. Color and contrast effects on temporal attention and integration

In Chapter 2, we studied the perceptual effects of the joint appearance of successive stimuli on temporal target identification and integration. Specifically, we investigated the effects of featural (color) and non-featural (luminance contrast) changes of RSVP target pairs in a series of experiments. The main manipulation in all experiments was that either target shared the same color/contrast, or the target colors/contrasts differed. Again, we were interested in whether target color/contrast pairs influenced temporal attention and integration. We observed that a categorical change in color increased target identification performance in experiment 1A and 1C, which was consistent with previously published findings in the literature (Akyürek, Köhne, & Schubö 2013).

According to the (e)STST model (Wyble, Bowman & Nieuwenstein 2009), the attentional blink reflects a cost of trying to build temporal episodes that are distinct from one another. The theory furthermore holds that increased featural similarity of targets should decrease the episodic distinctiveness of the targets; conversely, increased featural dissimilarity should increase episodic distinctiveness, which would explain why target identification accuracy was increased in the different color condition. This theory is compatible with increased target identification performance at Lag 3 as well as Lag 1, since dissimilarity of targets should increase episodic distinctiveness, as long as the targets appear within the typical attentional blink time-window.

Furthermore, this enhancement in identification performance was lost in experiment 1B where the color manipulation was slightly different. In experiment 1B, target colors were shades of blue so that the change in color was not as distinct as the categorical change in the previous experiments. As a result, the increased target identification performance in experiment 1A/C disappeared, which is in line with the (e)STST theory, because if target features are not much, or not categorically, distinct from each other, then episodic distinctiveness does not increase.

A change in color from one target stimulus to the next also increased perceptual integrations of the two targets at Lag 1, which was supported with direct evidence in experiment 1A and 1C. As mentioned above, in these experiments, target pairs either shared the same color (e.g., T1 & T2 were both blue) or their colors were different (e.g., T1 was blue and T2 was red). So, although none of the actually presented individual targets were multi-colored, in other words, real targets always had just one color, participants still tended to integrate differently colored targets more than same-color targets. Apparently, they thus did perceive these fully illusory, multi-colored, composite targets.

Apart from this increase in integration for target pairs of different colors, it must be noted we also found that when the color category did not change (e.g., different hues still both within the blue range; experiment 1B) integration rates were not influenced. A possible mechanism that may explain this finding is that same-colored targets trigger a segregation response opposing the tendency of integrating targets, in an effort to maintain episodic distinctiveness (cf. Bowman & Wyble, 2007; Wyble, Bowman & Nieuwenstein, 2009). This possible mechanism is supported by the previous finding that targets of the same color interfered at Lag 1 (Akyürek, Köhne, & Schubö, 2013), although the targets were spatially displaced in this previous study. Taken together, it may be concluded that a change in target color resulted in similar effects on target identification accuracy and temporal integrations, which may suggest that temporal integrations are at least partly influenced by attentional mechanisms.

The aforementioned findings stood in sharp disparity with the results obtained from a second experiment in which target contrast, a salient but non-featural stimulus property, was manipulated (Experiment 2A/B), suggesting that these two different manipulations influence attentional mechanisms differently. The contrast manipulation showed that high-contrast targets were identified more successfully, which can be attributed to greater saliency. Apart from this effect, target identification performance in same-contrast target pairs was also higher, and this effect was not only observed at Lag 1, instead, a main effect of contrast pairs was observed. Manipulating contrast did not affect integration frequency, however.

The identification effect might be explained by masking, so that high contrast target masks the preceding or following low-contrast target, which then interferes with the processing of low-contrast targets. It should be noted in this context that the target colors in Experiment 1 were iso-luminant, while target contrasts in Experiment 2 were obviously not, due to the nature of contrast. Hence, the experimental manipulations were conceptually similar (same or different color/contrast pairs), but different in physical target strength.

5.2. Gestalt effects on temporal attention and integration

It is known that Gestalt properties of stimuli influence perception. Individual stimuli that have Gestalt properties are typically grouped together in space and perceived as a single, whole object. There is evidence that a range of Gestalt properties, including proximity, connectedness, closure, symmetry, common fate, and continuity, influence visual perception in this way (Wagemans et al., 2012). Gestalt properties are generally thought to emerge at a relatively early stage of perceptual processing. For example, according to Marini and Marzi (2016), Gestalt properties capture visuo-spatial attention automatically.

Although spatial grouping effects of Gestalt properties have been studied extensively, there is only a limited number of studies investigating whether Gestalt properties influence cognitive functions in the temporal domain also. In other words, even if a complete Gestalt figure is not present at the same moment on a visual array, if ongoing stimuli do form a Gestalt over time, does that still influence the perception and processing of the stimuli? In order to test this, we used a hybrid temporal attention and integration dual-target RSVP task, where we investigated if Gestalt properties influence perception with regard to temporal integration and temporal attention.

In our experiments, we used a Kanizsa contour (also known as illusory contour), which is a Gestalt property, and which induces the perception of illusory shapes, even though there is no real contour shown. In chapter 3, we investigated if Kanizsa contours influence temporal attention and integration with four experiments. The main manipulation was whether stimuli formed an illusory shape (Kanizsa-present) or not (Kanizsa-absent). Although the main manipulation was about illusory contours, the target stimuli comprised other Gestalt properties as well (e.g., common fate, in which separate lines all point towards the same location). The study results showed that Kanizsa contours influence performance in dual-target RSVP tasks. However, not only Kanizsa contours but also other Gestalt properties increased the frequency of temporally integrated percepts of the two targets at Lag 1.

As alluded to above, Gestalts might primarily affect early visual processing. Neuroscientific studies have yielded evidence in favor of this idea. For instance, fMRI studies showed stronger responses to collinear elements compared to random elements in early visual areas (V1, V2, VP, and V4v) and in lateral occipital cortex (Altmann, Bulthoff, Kourtzi, 2003; Seghier & Vuilleumier, 2006). In addition, EEG studies have shown that early ERP components (P1 & N1) are influenced by Kanizsa shapes (Conci et al., 2011). Thus, these brain studies implicate early components and early visual areas. When stimuli are presented with longer delays in-between, such as when one or more distractors appear between targets in RSVP, that delay between the successive parts of the Kanizsa figure may have been sufficient to neutralize the benefits of Kanizsa contours on temporal attention beyond Lag 1 in the current RSVP design. Nevertheless, the results also showed that the presence of a good Gestalt, in general, can indeed facilitate temporal integration at Lag 1. Thus, although Kanizsa figures are apparently not special in this sense, Gestalt principles (such as common fate) do affect the early stages of temporal perception, as reflected by integration processes. Although we observed specific benefits of Kanizsa contours on T2|T1 accuracy in experiment 2 & 3B, the observed effects were not consistent in other experiments. It should be noted that differences between Gestalt and non-Gestalt figures were clearest in Experiment 2. Given that there were Gestalt properties present even in the Kanizsa-absent conditions in the other experiments, our findings suggest that Gestalt properties in general may facilitate temporal target identification and integration, presumably due to increased target compatibility.

5.3. The effects of cocoa flavanols

In Chapter 4, we investigated whether or not a change in mental state results in similar behavior in terms of temporal target identification and integration. Apart from temporal attention and integration, we also measured spatial attention by means of a visual search task. As explained in chapter 4, our research question was motivated by physiological evidence of nitric oxide (NO) synthesis as a result of CF consumption, which was proven in both laboratory experiments, and in living organisms (Karim, McCormick & Kappagoda, 2000; Fisher et al., 2003). NO induces vasodilation and can act as a neurotransmitter (Calver, Collier & Vallance, 1992; Garthwaite, 1991). Each or both of these mechanisms may cause the consumption of cocoa flavanols to affect cognitive functions. There is indeed prior neural and behavioral evidence of CF effects on cognition. However, even though neurophysiological studies show consistent findings in terms of CF effects on the brain, behavioral studies are mixed, with some studies showing better performance on cognitive tasks while others do not (for a review see Socci et al., 2017). It may be speculated that the main reason for these mixed effects is the nature of the tasks used, and variability in study designs, such as employing between-subject or within-subject designs, in the amount of administered CF, and in the inconsistent use of double-blind procedures (see chapter 4 for specific methodological comparisons between studies). It thus remained an open question whether robust effects of CF would emerge on selective attention and/or temporal integration.

The outcomes of our study firstly suggested that neither temporal attention nor temporal integration was acutely influenced by the consumption of cocoa flavanols. Although CF influences arterial cingulate cortex (Lamport et al., 2015), which has been found to modulate performance in AB tasks (Marois, Chun & Gore, 2000), we could not observe any benefits of CF on temporal attention and integration. However, it should be noted that it is conceivable that the measure of performance in the AB task (accuracy) is not sensitive enough to reliably observe CF effects. Behavioral studies with reaction time measurements are in general more sensitive to CF intake. A speeded RSVP design with RT measurements, therefore, similar to tasks that measure the psychological refractory period (Wong, 2002) may more decisively reveal whether any CF effects on temporal attention and integration exist.

We secondly observed that consumption of CF did acutely influence performance in our visual search (VS) task, which measured both the accuracy and speed of spatial attention. Again, the accuracy measure seemed less informative: CF did not influence the accuracy in VS tasks. Average accuracy in the VS task was 94%, which is quite high. A ceiling effect might thus have occurred, leaving too little room for improvement. Harder tasks that involve similar information processing (parallel and serial search) may be better suited to reveal CF effects on VS accuracy. It is generally well known that RTs in VS tasks are a better measurement than accuracy measurement due to the fact that finding a target on a visual array is a very simple task and the performance is often at ceiling, as we also observed (Akyürek & Schubö, 2011). Indeed, we observed faster RTs in the low dose condition than in the baseline and placebo conditions, when the target singleton in the visual array was absent. Furthermore, faster RTs were observed in the low/high dose conditions than in the baseline condition in target-present trials, when the non-target item was a tilted singleton.

Taken together, the outcomes of the RSVP and VS experiments suggest that spatial and temporal attention were not influenced by CF in the same way. This difference may be accounted for in several ways. First, there are some fundamental differences between the two tasks. Perhaps most important of all is the fact that target items in RSVP have other stimuli that appear as masks in the same location, both before and after the targets themselves. There is no masking in the VS task so that the processing of the target is not interrupted. Without such interruption, there may be more opportunity for CF-induced changes in target-related processing phases that occur at a later moment, which are cut short (partially) if a mask would have appeared. Thus, if the locus of the CF effect is relatively late, this may account for the different findings in RSVP and VS.

Furthermore, although CF should have the generic effect of increasing cerebral blood flow, there is no clear evidence that CF also generically enhances cognitive functions. Instead, the outcomes of previous studies show mixed results, and therefore it may be argued that CF influences specific cognitive functions rather than providing a general cognitive enhancement. This is also compatible with the presently observed effects in the VS task, and the lack thereof in the RSVP task. However, further research is certainly needed to have a better understanding of how specific attentional mechanisms are influenced by CF.

Finally, it must be noted that the hybrid AB/integration task was category-based as only discrete target identities were to be reported, and RTs were not collected. By contrast, RT was the principal measure in the VS task. As discussed, RT is probably a more sensitive measure of task performance in many cases, and this may have caused the differential results between tasks. This might be investigated directly in future research, for instance by measuring CF effects in a speeded AB task (cf. Akyürek, Hommel, & Jolicœur, 2007), or by using continuous, non-categorical report measures.

5.4. (Dis)similarities between RSVP and MET paradigms

In this dissertation, temporal integrations in RSVP tasks were investigated. Based on the results discussed in chapter 2, it may be argued that temporal integrations that are observed in RSVP and MET paradigms are different in nature. The results of the contrast Experiment (2A/B) suggested that temporal integration in dual-target RSVP designs and missing element tasks (MET) may be influenced differently by stimulus contrast. It has been shown in MET that integration is facilitated when the first display is high-contrast and the second is low-contrast compared to the reversed order of the displays and to same-contrast pairs (Akyürek & de Jong, 2017). However, we could not observe such effects in the RSVP task. This discrepancy is evidence that certain underlying integration mechanisms may be different in RSVP and MET.

First, integration of targets is unintentional in RSVP, because the task is to identify targets separately, and successive targets thus primarily compete with each other. Conversely, the goal in the MET is to integrate displays in order to spot the missing element, hence the integrations in MET are intentional. To elaborate, intentional and unintentional integrations may be conceived of as task rules. In intentional integrations, succesive targets have to be integrated in order to do the task correctly, however, if the task is to segregate targets, then integrations may be considered unintentional. Second, stimuli are shown at approximately 100 ms per item in RSVP, while most stimuli in MET tasks are shorter than that. Hence, processing of visual information is quicker in MET tasks. Thereby integration in the MET may rely more on basic visible persistence mechanisms, rather than more high-level and longer-lasting informational persistence (Coltheart, 1980; Irwin & Yeomas, 1986; Loftus & Irwin, 1998); the latter may play more of a role in RSVP. Third, in classical RSVP designs, targets and distractors appear on the same spatial location, so that integrating targets means binding two separate targets to the same spatial location, with focal attention. However, elements in display in MET do not spatially overlap, so that attention may be more dispersed. Fourth, the number of items (usually 25) in MET exceeds the limits of working memory, which is not the case in the present RSVP tasks. Although integration of succeeding targets seem similar behaviorally, the results of this dissertation suggest that temporal integrations in MET and RSVP paradigms are dissimilar.

5.5. Limitations and future directions

The main limitation of this thesis is that we only measured behavioral performance. Although there seems to be a degree of overlap between target identification performance and temporal integration, we do not know in which stage of information processing it occurs. Future studies that can apply neuro-imaging techniques would be informative in this case.

There are a couple of further research projects that could be done in the direction of the empirical chapters of this dissertation. In Chapter 2, we have shown that a categorical change in the color feature of targets facilitates temporal attention and integration. However, we did not test if these benefits can be generalized to other feature domains (orientation, motion, etc.). This question is important because different features are processed in different locations of the visual cortex [i.e., motion in middle temporal area (Liu & Pack, 2017), and orientation in V1 of the visual cortex (Blasdel &Salama, 1986)]. We also do not know yet if these benefits are a result of facilitation on the encoding or on the maintenance phase of the targets in working memory. One way to answer these two questions in a single research project is to use working memory mixture models (e.g. Zhang & Luck, 2008), where irrelevant target features (orientation, shape, color, motion) can be manipulated as a continuous spectrum with regard to similarity. This would allow a comparison of different model results, which could shed light on this unsolved question.

Furthermore, manipulations of target features can be tested in the MET in order to explore similarities/differences of integrations between intentional (MET) and unintentional (RSVP) integration. Similarly, to reveal shared and unique mechanisms of temporal integration as a function of Gestalt properties, these properties should be tested also in the MET.

Finally, with regard to the effects of cocoa flavanols, it is conceivable that the measure of performance in the AB task (accuracy) is not sensitive enough to reliably observe CF effects. A speeded RSVP design with RT measurements, similar to tasks that measure the psychological refractory period (Wong, 2002), may therefore more decisively reveal whether any CF effects on temporal attention and integration might still exist.

5.6. Conclusions

The present thesis reports a series of studies, investigating whether temporal target identification and integration share similar underlying cognitive mechanisms as stated at the beginning of this chapter. Overall, this dissertation suggests that temporal attention and integration in RSVP are influenced by exogenous stimuli properties and by a flavanol-induced change in mental state in a similar direction, especially when it comes to performance at Lag 1. More specifically: (I) Temporal integration and attention benefit from a categorical change of target colors due to reduced competition between targets. (II) A change in target strength increases temporal target identification but not integration suggesting that compatibility is most vital for integrations in RSVP. (III) Temporal attention and integration are facilitated when targets are compatible and form a figure with Gestalt properties. (IV) A flavanol-induced change in mental state did not result in an effect on identification and integration. Overall, it seems that temporal attention and integration share at least partly some underlying mechanisms. However, more research is needed in order to understand how these two phenomena relate to each other, particularly in terms of which information processing stages may show mutual overlap.

REFERENCES

Akyürek, E. G., & de Jong, R. (2017). Distortions of temporal integration and perceived order caused by the interplay between stimulus contrast and duration. *Consciousness and Cognition, 54*, 129–142. doi:10.1016/j.concog.2017.02.011

Akyürek, E. G., Eshuis, S. A. H., Nieuwenstein, M. R., Saija, J. D., Başkent, D., & Hommel, B. (2012). Temporal target integration underlies performance at Lag 1 in the attentional blink. *Journal of Experimental Psychology: Human Perception and Performance, 38*(6), 1448–1464. doi: 10.1037/a0027610

Akyürek, E. G., & Hommel, B. (2005). Target integration and the attentional blink. Acta *Psychologica, 119*(3), 305–314. doi: 10.1016/j.actpsy.2005.02.006

Akyürek, E. G., Hommel, B., & Jolicoeur, P. (2007). Direct evidence for a role of working memory in the attentional blink. *Memory & Cognition, 35*(4), 621–627. doi:10.3758/bf03193300

Akyürek, E. G., Kappelmann, N., Volkert, M., & van Rijn, H. (2017). What you see is what you remember: Visual chunking by temporal integration enhances working memory. *Journal of Cognitive Neuroscience*, 1–12. https://doi.org/10.1162/jocn_a_01175

Akyürek, E. G., Köhne, C., & Schubö, A. (2013). Task set flexibility and feature specificity modulate the limits of temporal attention. *Psychological Research, 77*(5), 583–598. https://doi.org/10.1007/s00426-012-0447-7

Akyürek, E. G., Riddell, P. M., Toffanin, P., & Hommel, B. (2007). Adaptive control of event integration: Evidence from event-related potentials. *Psychophysiology, 44*(3), 383–391. https://doi.org/10.1111/j.1469-8986.2007.00513.x

Akyürek, E. G., & Schubö, A. (2011). The allocation of attention in displays with simultaneously presented singletons. *Biological Psychology, 87,* 218-225. doi: 10.1016/j.biopsycho.2011.02.022

Akyürek, E. G., Schubö, A., & Hommel, B. (2013). Attentional control and competition between episodic representations. *Psychological Research, 77*, 492-507. https://doi.org/10.1007/s00426-012-0445-9

Akyürek, E. G., & Wolff, M. J. (2016). Extended temporal integration in rapid serial visual presentation: Attentional control at Lag 1 and beyond. *Acta Psychologica, 168*, 50–64. https://doi.org/10.1016/j.actpsy.2016.04.009

Altmann, C. F., Bülthoff, H. H., & Kourtzi, Z. (2003). Perceptual Organization of Local Elements into Global Shapes in the Human Visual Cortex. *Current Biology, 13*(4), 342–349. doi:10.1016/s0960-9822(03)00052-6

Bartsch, M. V., Loewe, K., Merkel, C., Heinze, H.-J., Schoenfeld, M. A., Tsotsos, J. K., & Hopf, J.-M. (2017). Attention to color sharpens neural population tuning via feedback processing in the human visual cortex hierarchy. *The*

Journal of Neuroscience, 37(43), 10346–10357. https://doi.org/10.1523/jneurosci.0666-17.2017

Bell, L., Lamport, D. J., Butler, L. T., & Williams, C. M. (2015). A review of the cognitive effects observed in humans following acute supplementation with flavonoids, and their associated mechanisms of action. *Nutrients, 7*(12), 10290-10306.

Benedetto, S., Carbone, A., Pedrotti, M., Le Fevre, K., Bey, L. A. Y., & Baccino, T. (2015). Rapid serial visual presentation in reading: The case of Spritz. *Computers in Human Behavior, 45,* 352–358. doi:10.1016/j.chb.2014.12.043

Blasdel, G. G., & Salama, G. (1986). Voltage-sensitive dyes reveal a modular organization in monkey striate cortex. *Nature, 321*(6070), 579–585. doi:10.1038/321579a0

Bowman, H., & Wyble, B. (2007). The simultaneous type, serial token model of temporal attention and working memory. *Psychological Review, 114*(1), 38–70. https://doi.org/10.1037/0033-295X.114.1.38

Bravo, L. (1998). Polyphenols: Chemistry, Dietary Sources, Metabolism, and Nutritional Significance. *Nutrition Reviews, 56*(11), 317–333. doi:10.1111/j.1753-4887.1998.tb01670

Brisson, B., Spalek, T. M., & Di Lollo, V. (2011). On the role of intervening distractors in the attentional blink. *Attention, Perception, and Psychophysics, 73*(1), 42–52. https://doi.org/10.3758/s13414-010-0003-8

Broadbent, D. E., & Broadbent, M. H. P. (1987). From detection to identification: Response to multiple targets in rapid serial visual presentation. *Perception & Psychophysics, 42*(2), 105–113. doi: 10.3758/bf03210498

Bush, G., Luu, P., & Posner, M. I. (2000). Cognitive and emotional influences in anterior cingulate cortex. *Trends in Cognitive Sciences, 4*(6), 215–222. doi:10.1016/s1364-6613(00)01483-2

Calver, A., Collier, J., & Vallance, P. (1992). Nitric oxide and blood vessels: physiological role and clinical implications. *Biochemical Education, 20*(3), 130–135. doi:10.1016/0307-4412(92)90048-q

Chua, F. K. (2005). The effect of target contrast on the attentional blink. *Perception & Psychophysics, 67*(5), 770–788. doi:10.3758/bf03193532

Chun, M. M., & Potter, M. C. (1995). A two-stage model for multiple target detection in rapid serial visual presentation. *Journal of Experimental Psychology: Human Perception and Performance, 21,* 109-127. doi: 10.1037/0096-1523.21.1.109

Coltheart, M. (1980). Iconic memory and visible persistence. *Perception & Psychophysics, 27*(3), 183–228. https://doi.org/10.3758/BF03204258

Conci, M., Böbel, E., Matthias, E., Keller, I., Müller, H. J., & Finke, K. (2009). Preattentive surface and contour grouping in Kanizsa figures: Evidence from parietal extinction. *Neuropsychologia, 47*, 726–732. doi: 10.1016/j.neuropsychologia.2008.11.029

Conci, M., & Muller, H. J. (2009). The "beam of darkness": Spreading of the attentional blink within and between objects. *Attention, Perception & Psychophysics, 71*(8), 1725–1738. doi:10.3758/app.71.8.1725

Conci, M., Töllner, T., Leszczynski, M., & Müller, H. J. (2011). The time-course of global and local attentional guidance in Kanizsa-figure detection. *Neuropsychologia, 49,* 2456–2464. doi: 10.1016/j.neuropsychologia.2011.04.023

Davis, G., & Driver, J. (1994). Parallel detection of Kanizsa subjective figures in the human visual system. *Nature, 371*, 791–793. doi: 10.1038/371791a0

Deary, I. J., Corley, J., Gow, A. J., Harris, S. E., Houlihan, L. M., Marioni, R. E., Penke, L., Rafnsson, S. B., & Starr, J. M. (2009). Age-associated cognitive decline. *British Medical Bulletin, 92*(1), 135–152. doi:10.1093/bmb/ldp033

Decroix, L., Tonoli, C., Soares, D. D., Tagougui, S., Heyman, E., & Meeusen, R. (2016). Acute cocoa flavanol improves cerebral oxygenation without enhancing executive function at rest or after exercise. *Applied Physiology, Nutrition, and Metabolism, 41*(12), 1225–1232. doi:10.1139/apnm-2016-0245

Di Lollo, V. (1980). Temporal integration in visual memory. *Journal of Experimental Psychology: General, 109*(1), 75–97. doi:10.1037/0096-3445.109.1.75

Di Lollo, V., Arnett, J. L., & Kruk, R. V. (1982). Age-related changes in rate of visual information processing. *Journal of Experimental Psychology: Human Perception and Performance, 8*(2), 225–237. doi: 10.1037/0096-1523.8.2.225.

Duncan, J., & Humphreys, G. W. (1989). Visual search and stimulus similarity. *Psychological Review, 96*(3), 433–458. https://doi.org/10.1037/0033-295X.96.3.433

Dux, P. E., & Marois, R. (2009). The attentional blink: A review of data and theory. *Attention, Perception & Psychophysics, 71*(8), 1683–1700. doi: 10.3758/APP.71.8.1683

Enns, J. T., & Di Lollo, V. (2000). What's new in visual masking? *Trends in Cognitive Sciences, 4*(9), 345–352. doi:10.1016/s1364-6613(00)01520-5

Field, D. T., Williams, C. M., & Butler, L. T. (2011). Consumption of cocoa flavanols results in an acute improvement in visual and cognitive functions. *Physiology & Behavior, 103*(3-4), 255–260. doi:10.1016/j.physbeh.2011.02.013

Fisher, N. D., Hughes, M., Gerhard-Herman, M., & Hollenberg, N. K. (2003). Flavanol-rich cocoa induces nitric-oxide-dependent vasodilation in healthy humans. *Journal of Hypertension, 21*(12), 2281–2286. doi:10.1097/00004872-200312000-00016

Folk, C. L., Leber, A. B., & Egeth, H. E. (2008). Top-down control settings and the attentional blink: Evidence for non-spatial contingent capture. *Visual Cognition, 16*(5), 616–642. https://doi.org/10.1080/13506280601134018

Francis, S. T., Head, K., Morris, P. G., & Macdonald, I. A. (2006). The Effect of Flavanol-rich Cocoa on the fMRI Response to a Cognitive Task in Healthy Young People. *Journal of Cardiovascular Pharmacology, 47*(Supplement 2), S215–S220. doi:10.1097/00005344-200606001-00018

Gao, Z, Gao, Q., Tang, N., Shui, R., & Shen, M. (2015). Organization principles in visual working memory: Evidence from sequential stimulus display. *Cognition, 146,* 277–288. doi: 10.1016/j.cognition.2015.10.005

Garner, K. G., Tombu, M. N., & Dux, P. E. (2014). The influence of training on the attentional blink and psychological refractory period. *Attention, Perception, & Psychophysics, 76*(4), 979–999. doi:10.3758/s13414-014-0638-y

Garthwaite, J. (1991). Glutamate, nitric oxide and cell-cell signalling in the nervous system. *Trends in Neurosciences, 14*(2), 60–67. doi:10.1016/0166-2236(91)90022-m

Giesbrecht. B., Bischof, W. F., & Kingstone, A. (2003). Visual masking during the attentional blink: Tests of the object substitution hypothesis. *Journal of Experimental Psychology: Human Perception and Performance, 29*(1), 238–258. doi: 10.1037/0096-1523.29.1.238

Grassi, D., Socci, V., Tempesta, D., Ferri, C., De Gennaro, L., Desideri, G., & Ferrara, M. (2016). Flavanol-rich chocolate acutely improves arterial function and working memory performance counteracting the effects of sleep deprivation in healthy individuals. *Journal of Hypertension, 34*(7), 1298–1308. doi:10.1097/hjh.0000000000000926

Grossberg, S., Mingolla, E., & Ross, W. D. (1997). Visual brain and visual perception: How does the cortex do perceptual grouping? *Trends in Neurosciences, 20*(3), 106–111. doi: 10.1016/s0166-2236(96)01002-8

Hilkenmeier, F., Olivers, C. N. L., & Scharlau, I. (2012). Prior entry and temporal attention: Cueing affects order errors in RSVP. *Journal of Experimental Psychology: Human Perception and Performance, 38*(1), 180–190. https://doi.org/10.1037/a0025978

Hogben, J. H., & Lollo, V. di. (1974). Perceptual integration and perceptual segregation of brief visual stimuli. *Vision Research, 14*(11), 1059–1069. doi:10.1016/0042-6989(74)90202-8

Hommel, B., & Akyürek, E. G. (2005). Lag-1 sparing in the attentional blink: Benefits and costs of integrating two events into a single episode. *The Quarterly*

Journal of Experimental Psychology, 58A (8), 1415–1433. doi: 10.1080/02724980443000647

Hooper, L., Kay, C., Abdelhamid, A., Kroon, P. A., Cohn, J. S., Rimm, E. B., & Cassidy, A. (2012). Effects of chocolate, cocoa, and flavan-3-ols on cardiovascular health: a systematic review and meta-analysis of randomized trials. *American Journal of Clinical Nutrition, 95*(3), 740–751. doi:10.3945/ajcn.111.023457

Hopf, J.-M., Boehler, C. N., Luck, S. J., Tsotsos, J. K., Heinze, H.-J., & Schoenfeld, M. A. (2006). Direct neurophysiological evidence for spatial suppression surrounding the focus of attention in vision. *Proceedings of the National Academy of Sciences, 103*(4), 1053–1058. https://doi.org/10.1073/pnas.0507746103

Irwin, D. E., & Yeomans, J. M. (1986). Sensory registration and informational persistence. *Journal of Experimental Psychology: Human Perception and Performance, 12*(3), 343–360. doi:10.1037/0096-1523.12.3.343

Jolicœur, P., & Dell'Acqua, R. (1998). The demonstration of short-term consolidation. *Cognitive Psychology, 36*(2), 138–202. doi: 10.1006/cogp.1998.0684

Kanwisher, N. G. (1987). Repetition blindness: Type recognition without token individuation. *Cognition, 27*(2), 117–143. doi:10.1016/0010-0277(87)90016-3

Karabay, A., & Akyürek, E. G. (2017). The effects of Kanizsa contours on temporal integration and attention in rapid serial visual presentation. *Attention, Perception, & Psychophysics, 79*(6), 1742–1754. doi:10.3758/s13414-017-1333-6

Karim, M., McCormick, K., & Kappagoda, C. T. (2000). Effects of Cocoa Extracts on Endothelium-Dependent Relaxation. *The Journal of Nutrition, 130*(8), 2105S–2108S. doi:10.1093/jn/130.8.2105s

Kellie, F. J., & Shapiro, K. L. (2004). Object file continuity predicts attentional blink magnitude. *Perception & Psychophysics, 66*(4), 692–712. doi:10.3758/bf03194912

Kinnucan, M. T., & Friden, T. P. (1981). Visual form integration and discontinuity detection. *Journal of Experimental Psychology: Human Perception and Performance, 7*(5), 948–953. doi:10.1037/0096-1523.7.5.948

Lamport, D. J., Pal, D., Moutsiana, C., Field, D. T., Williams, C. M., Spencer, J. P. E., & Butler, L. T. (2015). The effect of flavanol-rich cocoa on cerebral perfusion in healthy older adults during conscious resting state: a placebo controlled, crossover, acute trial. *Psychopharmacology, 232*(17), 3227–3234. doi:10.1007/s00213-015-3972-4

Lee, K. W., Kim, Y. J., Lee, H. J., & Lee, C. Y. (2003). Cocoa has more phenolic phytochemicals and a higher antioxidant capacity than teas and red wine. *Journal of Agricultural and Food Chemistry, 51*(25), 7292–7295. doi:10.1021/jf0344385

Lee, T. S. (2002). The nature of illusory contour computation. *Neuron, 33*(5), 667–668. doi: 10.1016/s0896-6273(02)00616-5

Leonte, A., Colzato, L. S., Steenbergen, L., Hommel, B., & Akyürek, E. G. (2018). Supplementation of gamma-aminobutyric acid (GABA) affects temporal, but not spatial visual attention. *Brain and Cognition, 120*, 8–16. doi:10.1016/j.bandc.2017.11.004

Li, X., Cave, K. R., & Wolfe, J. M. (2008). Kanizsa-type subjective contours do not guide attentional deployment in visual search but line termination contours do. *Perception & Psychophysics, 70*(3), 477–488. doi: 10.3758/pp.70.3.477

Loftus, G. R., & Irwin, D. E. (1998). On the relations among different measures of visible and informational persistence. *Cognitive Psychology, 35*(2), 135–199. https://doi.org/10.1006/cogp.1998.0678

Liu, L. D., & Pack, C. C. (2017). The Contribution of Area MT to Visual Motion Perception Depends on Training. *Neuron, 95*(2), 436–446.e3. doi:10.1016/j.neuron.2017.06.024

MacLean, M. H., & Arnell, K. M. (2010). Personality predicts temporal attention costs in the attentional blink paradigm. *Psychonomic Bulletin & Review, 17*(4), 556–562. doi:10.3758/pbr.17.4.556

MacLeod, C. M. (1991). Half a century of research on the Stroop effect: An integrative review. *Psychological Bulletin, 109*(2), 163–203. doi:10.1037/0033-2909.109.2.163

Maki, W. S., Bussard, G., Lopez, K., & Digby, B. (2003). Sources of interference in the attentional blink: Target-distractor similarity revisited. *Perception and Psychophysics, 65*(2), 188–201. https://doi.org/10.3758/BF03194794

Marini, F., & Marzi, C. A. (2016). Gestalt Perceptual Organization of Visual Stimuli Captures Attention Automatically: Electrophysiological Evidence. *Frontiers in Human Neuroscience, 10*. doi:10.3389/fnhum.2016.00446

Marois, R., Chun, M. M., & Gore, J. C. (2000). Neural correlates of the attentional blink. *Neuron, 28*(1), 299–308. doi:10.1016/s0896-6273(00)00104-5

Massee, L. A., Ried, K., Pase, M., Travica, N., Yoganathan, J., Scholey, A., … Pipingas, A. (2015). The acute and sub-chronic effects of cocoa flavanols on mood, cognitive and cardiovascular health in young healthy adults: a randomized, controlled trial. *Frontiers in Pharmacology, 6*. doi:10.3389/fphar.2015.00093

Mastroiacovo, D., Kwik-Uribe, C., Grassi, D., Necozione, S., Raffaele, A., Pistacchio, L., … Desideri, G. (2014). Cocoa flavanol consumption improves cognitive function, blood pressure control, and metabolic profile in elderly subjects: The cocoa, cognition, and aging (CoCoA) study--a randomized controlled trial. American *Journal of Clinical Nutrition, 101*(3), 538–548. doi:10.3945/ajcn.114.092189

McLaughlin, E. N., Shore, D. I., & Klein, R. M. (2001). The attentional blink is immune to masking-induced data limits. *The Quarterly Journal of Experimental Psychology, 54A* (1), 169–196. doi: 10.1080/02724980042000075

Murman, D. (2015). The impact of age on cognition. *Seminars in Hearing, 36*(03), 111–121. doi:10.1055/s-0035-1555115

Murray, S. O., Schrater, P., & Kersten, D. (2004). Perceptual grouping and the interactions between visual cortical areas. *Neural Networks, 17*(5-6), 695–705. doi: 10.1016/j.neunet.2004.03.010

Müsch, K., Engel, A. K., & Schneider, T. R. (2012). On the blink: The importance of target-distractor similarity in eliciting an attentional blink with Faces. *PLoS ONE, 7*(7), e41257. doi:10.1371/journal.pone.0041257

Nieuwenstein, M. R., Potter, M. C., & Theeuwes, J. (2009). Unmasking the attentional blink. *Journal of Experimental Psychology: Human Perception and Performance, 35*(1), 159–169. https://doi.org/10.1037/0096-1523.35.1.159

Olivers, C. N. L., & Meeter, M. (2008). A boost and bounce theory of temporal attention. *Psychological Review, 115*(4), 836–863. https://doi.org/10.1037/a0013395

Paine, T. A., Slipp, L. E., & Carlezon, W. A. (2011). Schizophrenia-like attentional deficits following blockade of prefrontal cortex GABAA receptors. *Neuropsychopharmacology, 36*(8), 1703–1713. doi:10.1038/npp.2011.51

Pase, M. P., Scholey, A. B., Pipingas, A., Kras, M., Nolidin, K., Gibbs, A., … Stough, C. (2013). Cocoa polyphenols enhance positive mood states but not cognitive performance: a randomized, placebo-controlled trial. *Journal of Psychopharmacology, 27*(5), 451–458. doi:10.1177/0269881112473791

Perez, V. B., & Vogel, E. K. (2012). What ERPs can tell us about working memory. Oxford Handbooks Online. doi:10.1093/oxfordhb/9780195374148.013.0180

Potter, M. C., Chun, M. M., Banks, B.S., & Muckenhoupt, M. (1998). Two attentional deficits in serial target search: The visual attentional blink and an amodal task-switch deficit. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 24,* 979–992. doi: 10.1037/0278-7393.24.4.979

Potter, M. C., Staub, A., & O'Connor, D. H. (2002). The time course of competition for attention: Attention is initially labile. *Journal of Experimental Psychology: Human Perception and Performance, 28*(5), 1149–1162. https://doi.org//10.1037//0096-1523.28.5.1149

Raymond, J. E., Shapiro, K. L., & Arnell, K. M. (1992). Temporary suppression of visual processing in an RSVP task: An attentional blink? *Journal of Experimental Psychology: Human Perception and Performance, 18*, 849–860. doi: 10.1037/0096-1523.18.3.849

Ronconi, L., Pincham, H. L., Cristoforetti, G., Facoetti, A., & Szűcs, D. (2016). Shaping prestimulus neural activity with auditory rhythmic stimulation improves the temporal allocation of attention. *NeuroReport, 27*(7), 487–494. https://doi.org/10.1097/wnr.0000000000000565

Ronconi, L., Pincham, H. L., Szűcs, D., & Facoetti, A. (2015). Inducing attention not to blink: Auditory entrainment improves conscious visual processing. *Psychological Research, 80*(5), 774–784. https://doi.org/10.1007/s00426-015-0691-8

Saenz, M., Buracas, G. T., & Boynton, G. M. (2002). Global effects of feature-based attention in human visual cortex. *Nature Neuroscience, 5*(7), 631–632. https://doi.org/10.1038/nn876

Saija, J. D., Başkent, D., Andringa, T. C., & Akyürek, E. G. (2017). Visual and auditory temporal integration in healthy younger and older adults. *Psychological Research.* doi:10.1007/s00426-017-0912-4

Scholey, A. B., French, S. J., Morris, P. J., Kennedy, D. O., Milne, A. L., & Haskell, C. F. (2009). Consumption of cocoa flavanols results in acute improvements in mood and cognitive performance during sustained mental effort. *Journal of Psychopharmacology, 24*(10), 1505–1514. doi:10.1177/0269881109106923

Seghier, M. L., & Vuilleumier, P. (2006). Functional neuroimaging findings on the human perception of illusory contours. *Neuroscience and Biobehavioral Reviews, 30*(5), 595-612. doi: 10.1016/j.neubiorev.2005.11.002

Seiffert, A. E., & Di Lollo, V. (1997). Low-level masking in the attentional blink. *Journal of Experimental Psychology: Human Perception and Performance, 23*(4), 1061–1073. doi: 10.1037/0096-1523.23.4.1061

Simione, L., Akyürek, E. G., Vastola, V., Raffone, A., & Bowman, H. (2017). Illusions of integration are subjectively impenetrable: Phenomenological experience of Lag 1 percepts during dual-target RSVP. *Consciousness and Cognition, 51,* 181–192. doi:10.1016/j.concog.2017.03.004

Socci, V., Tempesta, D., Desideri, G., De Gennaro, L., & Ferrara, M. (2017). Enhancing human cognition with cocoa flavonoids. *Frontiers in Nutrition, 4*. doi:10.3389/fnut.2017.00019

Sokolov, A. N., Pavlova, M. A., Klosterhalfen, S., & Enck, P. (2013). Chocolate and the brain: Neurobiological impact of cocoa flavanols on cognition and behavior. *Neuroscience & Biobehavioral Reviews, 37*(10), 2445–2453. doi:10.1016/j.neubiorev.2013.06.013

Spencer, J. P. E. (2007). The interactions of flavonoids within neuronal signalling pathways. *Genes and Nutrition, 2,* 257-273. doi: 10.1007/s12263-007-0056-z

Störmer, V. S., & Alvarez, G. A. (2014). Feature-based attention elicits surround suppression in feature space. *Current Biology, 24*(17), 1985–1988. https://doi.org/10.1016/j.cub.2014.07.030

Sy, J. L., & Giesbrecht, B. (2009). Target-target similarity and the attentional blink: Task-relevance matters! *Visual Cognition, 17*(3), 307–317. https://doi.org/10.1080/13506280802349746

Taatgen, N. A., Juvina, I., Schipper, M., Borst, J. P., & Martens, S. (2009). Too much control can hurt: A threaded cognition model of the attentional blink. *Cognitive Psychology, 59*(1), 1–29. https://doi.org/10.1016/j.cogpsych.2008.12.002

Treisman, A. M., & Gelade, G. (1980). A feature-integration theory of attention. *Cognitive Psychology, 12*(1), 97–136. https://doi.org/10.1016/0010-0285(80)90005-5

Treisman, A. M., & Kanwisher, N. G. (1998). Perceiving visually presented objects: Recognition, awareness, and modularity. *Current Opinion in Neurobiology*. https://doi.org/10.1016/S0959-4388(98)80143-8

Vauzour, D., Vafeiadou, K., Rodriguez-Mateos, A., Rendeiro, C., & Spencer, J. P. E. (2008). The neuroprotective potential of flavonoids: A multiplicity of effects. *Genes and Nutrition, 3*(3-4), 115–126. doi:10.1007/s12263-008-0091-4

Visser, T. A. W. (2007). Masking T1 difficulty: Processing time and the attentional blink. *Journal of Experimental Psychology: Human Perception and Performance, 33*(2), 285–297. doi: 10.1037/0096-1523.33.2.285

Visser, T. A. W., Bischof, W. F., & Di Lollo, V. (1999). Attentional switching in spatial and non-spatial domains: Evidence from the attentional blink. *Psychological Bulletin, 125*(4), 458–469. https://doi.org/10.1037/0033-2909.125.4.458

Visser, T. A. W., & Ohan, J. V. (2011). Is all sparing created equal? Lag-1 sparing and extended sparing in temporal object perception. *Journal of Experimental Psychology: Human, Perception and Performance, 34*(5), 1527–1541. doi: 10.1037/a0023508

Vogel, E. K., & Machizawa, M. G. (2004). Neural activity predicts individual differences in visual working memory capacity. *Nature, 428*(6984), 748–751. doi:10.1038/nature02447

Von Mühlenen, A., & Conci, M. (2016). The role of unique color changes and singletons in attention capture. *Attention, Perception, & Psychophysics, 78*(7), 1926–1934. doi:10.3758/s13414-016-1139-y

Von Mühlenen, A., Rempel, M. I., & Enns, J. T. (2005). Unique temporal change is the key to attentional capture. *Psychological Science, 16*(12), 979–986. doi:10.1111/j.1467-9280.2005.01647.x

Wagemans, J., Elder, J. H., Kubovy, M., Palmer, S. E., Peterson, M. A., Singh, M., & von der Heydt, R. (2012). A century of Gestalt psychology in visual perception: I. Perceptual grouping and figure–ground organization. *Psychological Bulletin, 138*(6), 1172–1217. doi: 10.1037/a0029333

Ward, R., Duncan, J., & Shapiro, K. L. (1997). Effects of similarity, difficulty, and nontarget presentation on the time course of visual attention. *Perception & Psychophysics, 59*(4), 593–600. doi: 10.3758/BF03211867

Wertheimer, M. (1938). Untersuchungen zur Lehre von der Gestalt II. *Psychologische Forschung, 4*, 301–350. doi: 10.1007/bf00410640

Wolfe, J. M. (1994). Guided Search 2.0 A revised model of visual search. *Psychonomic Bulletin & Review, 1*(2), 202–238. https://doi.org/10.3758/BF03200774

Wolfe, J. M. (1998). What can 1 million trials tell us about visual search? *Psychological Science, 9*(1), 33–39. doi:10.1111/1467-9280.00006

Wolff, M. J., Scholz, S., Akyürek, E. G., & van Rijn, H. (2015). Two visual targets for the price of one? Pupil dilation shows reduced mental effort through temporal integration. *Psychonomic Bulletin & Review, 22*(1), 251–257. doi:10.3758/s13423-014-0667-5

Wong, K. F. E. (2002). The relationship between attentional blink and psychological refractory period. *Journal of Experimental Psychology: Human Perception and Performance, 28*(1), 54–71. doi:10.1037/0096-1523.28.1.54

Wyble, B., Bowman, H., & Nieuwenstein, M. (2009). The attentional blink provides episodic distinctiveness: Sparing at a cost. *Journal of Experimental Psychology: Human Perception and Performance, 35*(3), 787–807. https://doi.org/10.1037/a0013902

Zhang, W., & Luck, S. J. (2008). Discrete fixed-resolution representations in visual working memory. *Nature, 453*(7192), 233–235. doi:10.1038/nature06860

APPENDIX

Appendix 1

T1 and T2 color/contrast -specific performance

Average T1 accuracy for specific T1 and T2 colors and contrasts is presented in Table A1.1. Table A1.2 shows average T2|T1 accuracy. Table A1.3 shows average temporal integration frequency. Table A1.4 shows order reversal frequency.

Table A1.1. Average T1 accuracy by T1 color/contrast, T2 color/contrast and lag across experiments.

Exp.	**T1-B**				**T1-R**			
1A	**T2-B**		**T2-R**		**T2-B**		**T2-R**	
	M	*S*	*M*	*S*	*M*	*S*	*M*	*S*
L_1	49.3	3.5	41.2	4.5	41.7	4.5	53.1	3.4
L_3	82.8	2.6	85.2	2.4	80.5	2.4	82.3	2.0
L_8	90.2	1.7	89.7	1.8	92.8	1.6	92.5	1.3

Exp.	**T1-B**				**T1- FB**			
1B	**T2-B**		**T2- FB**		**T2-B**		**T2-FB**	
	M	***S***	***M***	***S***	***M***	***S***	***M***	***S***
L_1	52.1	3.1	56.9	2.9	46.4	2.8	50.7	2.9
L_3	86.0	2.2	86.3	2.0	85.9	1.9	84.5	2.7
L_8	91.3	2.1	92.5	1.3	90.9	1.8	89.9	2.0

Exp.	**T1-B**						**T1-R**						**T1-G**					
1C	**T2-B**		**T2-R**		**T2-G**		**T2-B**		**T2-R**		**T2-G**		**T2-B**		**T2-R**		**T2-G**	
	M	***S***	***M***	***S***	***M***	***S***	***M***	***S***	***M***	***S***	***M***	***S***	***M***	***S***	***M***	***S***	***M***	***S***
L_1	43.6	3.3	32.1	3.5	40.9	4.1	35.7	4.5	44.6	2.9	38.1	5.0	19.1	2.9	31.2	4.0	40.5	2.9
L_3	83.4	3.1	87.6	1.8	83.8	2.8	84.8	3.1	86.2	1.6	87.6	2.6	3.4	1.2	85.5	2.5	78.8	2.9
L_8	91.4	1.8	90.3	2.2	90.3	1.8	91.4	2.0	94.0	1.8	92.4	1.9	2.1	0.0	88.6	2.6	90.9	1.7

Exp.	**T1-H**				**T1-L**			
2A	**T2-H**		**T2-L**		**T2-H**		**T2-L**	
	M	***S***	***M***	***S***	***M***	***S***	***M***	***S***
L_1	51.0	3.2	55.1	2.8	42.2	2.3	45.5	2.7
L_3	89.8	2.3	89.1	2.6	83.9	3.3	87.0	2.4
L_8	94.3	1.8	92.0	2.3	91.2	2.3	93.2	2.0

Exp.	**T1-H**				**T1-L**			
2B								
	T2-H		**T2-L**		**T2-H**		**T2-L**	
	M	***S***	***M***	***S***	***M***	***S***	***M***	***S***
L_1	55.6	3.3	62.4	3.6	45.7	3.2	50.0	3.6
L_3	89.2	1.9	88.2	2.2	85.4	2.2	85.8	2.4
L_8	93.2	1.5	95.3	1.9	90.5	1.9	92.5	1.7

L_1 = Lag 1; L_3 = Lag 3; L_8 = Lag 8; M= Mean (%); S = Standard error of the mean (%); B = Blue; R = Red; FB = Faded blue; G = Green; L = Low contrast; H = High contrast.

Table A1.2. Average T2|T1 accuracy by T1 color/contrast, T2 color/contrast and lag across experiments.

Exp. 1A	**T1-B**				**T1-R**			
	T2-B		**T2-R**		**T2-B**		**T2-R**	
	M	***S***	***M***	***S***	***M***	***S***	***M***	***S***
L_1	42.2	5	64.4	5.5	58.4	5.8	41.1	4.3
L_3	67.1	4.2	68.5	4.1	65	4	70.1	3.4
L_8	85.7	2.9	87	2.6	85.6	3.4	89.4	3

Exp. 1B	**T1-B**				**T1- FB**			
	T2-B		**T2-FB**		**T2-B**		**T2-FB**	
	M	***S***	***M***	***S***	***M***	***S***	***M***	***S***
L_1	70.1	3.6	59.4	4.5	72.4	3.0	62.9	3.9
L_3	80.5	3.4	71.1	4.0	82.3	3.0	74.6	3.9
L_8	89.2	2.3	88.9	2.3	91.4	1.6	86.1	2.3

Exp. 1C	**T1-B**						**T1-R**						**T1-G**					
	T2-B		**T2-R**		**T2-G**		**T2-B**		**T2-R**		**T2-G**		**T2-B**		**T2-R**		**T2-G**	
	M	***S***	***M***	***S***	***M***	***S***	***M***	***S***	***M***	***S***	***M***	***S***	***M***	***S***	***M***	***S***	***M***	*S*
L_1	40.5	4.9	56.4	5.7	66.3	5.7	58.9	6.5	44,7	4,8	63,2	7,2	7,5	4,3	67,5	6,6	36,1	5,2
L_3	68.6	3.2	76.2	3.6	73.7	4	78.1	3.5	76,7	3,7	67	4,2	0	0	76,5	4,4	60,4	4,2
L_8	88.2	2.4	90.6	3.1	84.5	3.5	89.9	2.1	89	2,2	89,6	2,2	0	0	87,8	3,3	85,4	2,8

Exp. 2A	**T1-H**				**T1-L**			
	T2-H		**T2-L**		**T2-H**		**T2-L**	
	M	***S***	***M***	***S***	***M***	***S***	***M***	***S***
L_1	71.2	3.8	54.9	4.7	72.0	3.7	65.5	4.7
L_3	76.5	4.4	59.9	4.7	75.6	4.4	67.2	4.9
L_8	91.4	2.6	88.0	3.4	89.5	2.8	87.4	2.6

Exp. 2B	**T1-H**				**T1-L**			
	T2-H		**T2-L**		**T2-H**		**T2-L**	
	M	***S***	***M***	***S***	***M***	***S***	***M***	***S***
L_1	69.6	5.0	54.2	4.9	71.9	4.6	63.9	4.5
L_3	75.9	3.6	61.5	5.3	76.3	4.0	70.5	4.3
L_8	94.6	1.5	90.7	1.8	92.0	1.8	90.5	1.8

L_1 = Lag 1; L_3 = Lag 3; L_8 = Lag 8; M= Mean (%); S = Standard error of the mean (%); B = Blue; R = Red; FB = Faded blue; G = Green; L = Low contrast; H = High contrast.

Table A1. 3. Average temporal integration frequency by T1 color/contrast, T2 color/contrast and lag across experiments.

Exp. 1A	T1-B				T1-R			
	T2-B		T2-R		T2-B		T2-R	
	M	S	M	S	M	S	M	S
L_1	10.9	2.6	19.2	4.9	19.7	4.9	10.8	2.6
L_3	0.3	0.2	0.7	0.3	0.8	0.3	0.7	0.3
L_8	0	0	0.3	0.2	0.2	0.2	0.2	0.2

Exp. 1B	T1-B				T1- FB			
	T2-B		T2- FB		T2-B		T2- FB	
	M	S	M	S	M	S	M	S
L_1	6.4	2.3	8.3	2.3	7.3	2.2	7.4	2.2
L_3	0.0	0.0	1.2	0.5	0.9	0.6	0.3	0.3
L_8	0.1	0.1	0.7	0.7	0.3	0.3	0.4	0.2

Exp. 1C	T1-B						T1-R						T1-G					
	T2-B		T2-R		T2-G		T2-B		T2-R		T2-G		T2-B		T2-R		T2-G	
	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S
L_1	15.4	2.7	32.9	5.2	27.2	5.2	33.4	5.4	16,9	3,3	31,6	6	4	0,9	32,4	5,6	17,8	3,2
L_3	1.7	0.9	1.4	1.1	2.8	1.1	1.4	0.8	1	0,5	1,4	0,8	4,1	1,4	1,4	1,1	2,6	1
L_8	0.3	0.2	0	0	0	0	0	0	0	0	1	0,6	3,1	1,3	0,3	0,3	0,5	0,3

Exp. 2A	T1-H				T1-L			
	T2-H		T2-L		T2-H		T2-L	
	M	S	M	S	M	S	M	S
L_1	8.1	2.4	9.0	2.6	7.8	2.5	11.4	3.0
L_3	0.0	0.0	0.5	0.5	0.7	0.3	0.4	0.2
L_8	0.0	0.0	0.4	0.2	0.0	0.0	0.2	0.2

Exp. 2B	T1-H				T1-L			
	T2-H		T2-L		T2-L		T2-H	
	M	S	M	S	M	S	M	S
L_1	6.6	1.8	6.7	2.2	7.6	2.7	8.4	2.5
L_3	0.7	0.7	1	0.5	0.7	0.3	1.9	0.7
L_8	0.2	0.2	0.3	0.2	0	0	0.5	0.3

L_1 = Lag 1; L_3 = Lag 3; L_8 = Lag 8; M= Mean (%); S = Standard error of the mean (%); B = Blue; R = Red; FB = Faded blue; G = Green; L = Low contrast; H = High contrast.

Table A1.4. Average order reversals by T1 color/contrast, T2 color/contrast and lag across experiments.

Exp.	**T1-B**				**T1-R**			
1A	**T2-B**		**T2-R**		**T2-B**		**T2-R**	
	M	***S***	***M***	***S***	***M***	***S***	***M***	***S***
L_1	6.7	1.1	11.5	1.9	10.4	1.6	5.5	1.0
L_3	1.7	0.6	2.0	0.5	3.5	1.0	2.3	0.6
L_8	1.3	0.5	1.7	0.6	0.5	0.3	1.0	0.4

Exp.	**T1-B**				**T1- FB**			
1B	**T2-B**		**T2- FB**		**T2-B**		**T2- FB**	
	M	***S***	***M***	***S***	***M***	***S***	***M***	***S***
L_1	10.8	1.2	8.9	1.1	13.4	1.3	11.4	1.2
L_3	2.6	0.5	2.7	0.7	1.6	0.4	3.2	0.8
L_8	0.9	0.4	0.9	0.4	1.5	0.6	1.2	0.4

Exp.	**T1-B**						**T1-R**						**T1-G**					
1C	**T2-B**		**T2-R**		**T2-G**		**T2-B**		**T2-R**		**T2-G**		**T2-B**		**T2-R**		**T2-G**	
	M	***S***	***M***	***S***	***M***	***S***	***M***	***S***	***M***	***S***	***M***	***S***	***M***	***S***	***M***	***S***	***M***	***S***
L_1	6.7	1.2	9.5	1.8	7.2	1.4	7.8	1.7	7,0	1,4	5,2	1,2	0,3	0,2	10,0	2,0	6,9	1,6
L_3	2.8	0.7	2.1	0.9	2.4	0.9	2.4	0.9	1,6	0,4	0,7	0,5	0,3	0,3	2,8	1,0	1,9	0,6
L_8	1.0	0.4	2.1	0.9	2.4	0.8	1.4	0.7	0,7	0,3	1,0	0,6	0,3	0,3	2,1	0,9	1,2	0,5

Exp.	**T1-H**				**T1-L**			
2A	**T2-H**		**T2-L**		**T2-H**		**T2-L**	
	M	***S***	***M***	***S***	***M***	***S***	***M***	***S***
L_1	14.8	2.1	12.4	2.2	16.7	1.8	16.3	1.9
L_3	2.4	0.8	1.9	0.8	2.8	0.9	2.8	0.8
L_8	1.0	0.4	0.9	0.5	1.2	0.5	1.2	0.5

Exp.	**T1-H**				**T1-L**			
2B								
	T2-H		**T2-L**		**T2-H**		**T2-L**	
	M	***S***	***M***	***S***	***M***	***S***	***M***	***S***
L_1	12.1	1.5	9.6	1.6	13.5	1.5	12.9	1.7
L_3	1.6	0.7	1.7	0.6	2.1	0.8	3.1	0.9
L_8	0.4	0.3	0.4	0.2	1.7	0.6	1.2	0.6

L_1 = Lag 1; L_3 = Lag 3; L_8 = Lag 8; M= Mean (%); S = Standard error of the mean (%); B = Blue; R = Red; FB = Faded blue; G = Green; L = Low contrast; H = High contrast.

T1 and T2 color/contrast-specific ANOVA results

In Table A1.5, target color/contrast-specific repeated measures ANOVA results are shown. *F* values are reported with mean square error within groups (MSW), so that pairwise comparisons can be calculated with Tukey's HSD post hoc test by using MSW, the means from Table A1.5.1-3, and the number of participants.

Table A1.5. ANOVA table for the main effects of T1 color/contrast, T2 color/contrast, and lag, with all possible interaction effects across experiments. Cross signs (†) next to F values indicate significance.

		Exp.1A		Exp.1B		Exp.1C		Exp.2A		Exp.2B	
		F	*MSW*	*F*	*MSW*	*F*	*MSW*	*F*	*MSW*	*F*	*MSW*
T1 ACC	*T1C*	1.0	.004	16.3†	.004	506.2†	.011	42.4†	.004	57.8†	.004
	T2C	4.3†	.002	8.9†	.002	358.1†	.010	4.6†	.004	8.1†	.005
	L	165.9†	.051	243.7†	.033	174.9†	.167	186.6†	.052	204.2†	.036
	T1C x T2C	4.9†	.016	.4	.012	202.6†	.030	.6	.009	.1	.003
	T1C x L	4.8†	.005	6.1†	.004	60.5†	.007	9.5†	.005	12.9†	.004
	T2C x L	0.9	.005	5.1†	.005	63.3†	.009	2.4	.004	5.1†	.004
	T1C x T2C x L	8.3†	.013	.1	.005	48.6†	.015	1.0	.004	0.4	.006
T2|T1 ACC	*T1C*	.65	.010	6.1†	.005	264.1†	.022	9.0†	.006	8.7†	.008
	T2C	8.6†	.007	48.0†	.010	120.9†	.042	54.2†	.011	38.6†	.012
	L	44.9†	.093	47.1†	.040	36.2†	.258	18.3†	.103	26.7†	.072
	T1C x T2C	10.3†	.022	.1	.025	108.1†	.049	4.0†	.019	13.2†	.005
	T1C x L	1.3	.011	1.4	.008	5.6†	.033	4.3†	.007	4.4†	.008
	T2C x L	0.6	.008	6.8†	.008	3.8†	.034	13.9†	.005	8.2†	.007
	T1Cx T2C xL	22.4	.021	1.2	.011	14.1†	.048	1.0	.016	.9	.007
Int.	*T1C*	4.8†	.001	.0	.000	7.0†	.005	.3	.001	4.8†	.001
	T2C	2.1	.001	7.6†	.000	7.5†	.009	6.9†	.001	2.1	.001
	L	10.0†	.028	10.2†	.038	38.9†	.215	12.5†	.039	10.0†	.028
	T1C x T2C	2.2	.002	1.5	.003	11.4†	.021	.0	.002	2.2	.000
	T1C x L	2.5	.001	.0	.001	14.1†	.013	2.1	.001	2.5	.001
	T2C x L	2.5	.001	1.5	.000	14.8†	.014	6.4†	.001	.3	.001
	T1C xT2C x L	0.05	.001	.5	.002	15.9†	.037	1.3	.003	.1	.001
Rev.	*T1C*	.5	.001	7.2†	.001	6.2†	.002	5.6†	.002	15.9†	.001
	T2C	.0	.001	1.0	.002	7.6†	.002	2.2	.001	1.1	.001
	L	35.1†	.004	86.2†	.006	22.2†	.010	53.4†	.010	62.1†	.006
	T1C x T2C	11.7†	.002	.3	.001	9.4†	.002	1.3	.002	.8	.001
	T1C x L	3.9†	.001	6.2†	.001	1.1	.001	4.2†	.001	.9	.002
	T2C x L	.3	.001	4.7†	.002	5.1†	.002	1.0	.001	1.7	.002
	T1C xT2C x L	9.9†	.002	.4	.002	2.3	.002	.4	.001	.6	001

F = F value of the repeated measures ANOVA; MSW = Mean square error within groups; T1 ACC = T1 accuracy; T2|T1 ACC = T2 accuracy in the trials that T1 identified correctly;

Int. = Temporal integration; Rev. = Order reversals; T1C = Main effect of T1 color or contrast; T2C = Main effect of T2 color or contrast; L = Main effect of Lag; x = interaction effect

Appendix 2

There were complete Kanizsa/non-Kanizsa figures when four corner segments of the stimuli were present in all four experiments. On the basis of previous findings (Nie et al., 2016), one might argue that the results of the study might be different in terms of T2|T1 accuracy and temporal integration if the comparison of Kanizsa-present and Kanizsa-absent conditions in trials that T1 and T2 form a complete figure (with 4 corner segments). A repeated measures ANOVA was adopted for testing Kanizsa effects on T2|T1 accuracy when T1 and T2 form a complete figure, and a paired sample t-test for temporal integration, because integrations mostly occur at lag 1. ANOVA and t-test results revealed an identical pattern of difference between conditions for both T2|T1 accuracy and temporal integration except for T2|T1 performance of Experiment 1. Table A2.1 shows ANOVA results of T2|T1 accuracy and Table A2.2 shows t-test results for temporal integration.

*Table. A2.1. Average T2|T1 accuracy and ANOVA results (an asterisk symbol * indicates significant F values) in the trials on which the combination of T1 and T2 formed a full figure (4 corner segments)*

		Lag1		Lag 3		Lag 8		*F*	
		Mean (%)	*SEM*	Mean (%)	*SEM*	Mean (%)	*SEM*	Kanizsa	Kanizsa×Lag
Exp. 1	KP	55.2	6	85.0	2.7	85.8	2.0	3.2	8.5*
	KA	42.2	7.1	84.0	4.1	89.5	2.6		
Exp. 2	KP	62.8	6.4	90.7	2.9	93.4	2.2	28.2*	24.5*
	KA	25.8	6.0	88.7	2.9	91.9	2.8		
Exp. 3A	KP	65.5	8.5	85.0	5.2	88.9	4.7	.1	.9
	KA	69.1	8.1	85.1	5.6	85.0	5.6		
Exp. 3B	KP	69.2	7.4	87.0	4.4	94.0	1.8	17.6*	23.0*
	KA	48.0	7.2	79.3	4.5	84.4	4.6		

KP = Kanizsa-present; KA = Kanizsa-absent condition

Table. A2.2. Average temporal integration and paired-sample t-test results at Lag 1 in the trials on which the combination T1 and T2 formed a full figure (4 corner segments)

		Lag 1		*t*	*p*
		Mean (%)	*SEM*		
Exp. 1	KP	7.6	1.9	1.4	>.05
	KA	5.1	1.3		
Exp. 2	KP	19.3	2.2	2.3	<.05
	KA	13.1	2.0		
Exp. 3A	KP	25.3	4.3	3.6	<.01
	KA	36.9	5.9		
Exp. 3B	KP	29.6	5.2	0.2	>.05
	KA	30.0	4.0		

KP = Kanizsa-present; KA = Kanizsa-absent condition

A blocked design was used in the study so that Kanizsa-present and Kanizsa-absent trials were shown in separate blocks. Starting with Kanizsa-present trials might have a learning effect that enhances temporal integration percentage in the second, Kanizsa-absent, block, or vice versa. A repeated measures ANOVA was run to investigate the main effect of block-order, the interaction of block-order and Kanizsa, and the interaction of block-order, Kanizsa, and lag. Neither the main effect of blockorder nor any two-way interaction effects with Kanizsa were significant on temporal integration. A three-way interaction effect was observed in Experiment 3A; integration was more frequent in the Kanizsa-absent condition, when participants started with the Kanizsa-absent block (50% vs. 36.9%).

Table. A2.3. Block-order effects across all experiments (significant results are indicated with an asterisk)

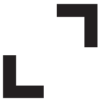
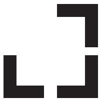
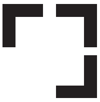
	F		
	Block-order	Block-order× Kanizsa	Block-order ×Kanizsa×Lag
Exp. 1	.14	.26	.62
Exp. 2	.16	.14	.01
Exp. 3A	.31	3.21	7.02*
Exp. 3B	.78	1.02	3.31

Appendix 3

Possible targets in RSVP

Possible targets in the RSVP task consisted of corner segments of a square, listed in the table below. Targets were randomly chosen (without replacement) from this set, with the only requirement that the two targets did not overlap within a single trial. In other words, the targets never contained the same corner segments

Table. A3.1. Possible targets in RSVP. CS means corner segments, and the number in front indicates the number of corner segments that the targets consisted of

Number of Corner Segments	Possible Targets					
1CS-Target						
2CS-Target						
3CS-Target						
4CS-Target						

Correlation matrix of accuracy and RT of VS task

A correlation matrix of accuracy and RT in the VS task is shown in the table below. As can be seen from the table A3.2, there were only two significant correlations between RT and accuracy. The overall pattern of correlations does not support the idea that speed might have been traded for accuracy.

Table. A3.2. The Pearson correlation matrix of accuracy and RT in the VS task

	Baseline_TP_NTC	Placebo_TP_NTC	LowDose_TP_NTC	HighDose_TP_NTC
	ACC	*ACC*	*ACC*	*ACC*
RT	-.10	-.24	-.06	-.10
	Baseline_TP_NTO	Placebo_TP_NTO	LowDose_TP_NTO	HighDose_TP_NTO
	ACC	*ACC*	*ACC*	*ACC*
RT	.11	-.30*	-.07	-.50
	Baseline_TA_NTC	Placebo_TA_NTC	LowDose_TA_NTC	HighDose_TA_NTC
	ACC	*ACC*	*ACC*	*ACC*
RT	-.23	-.34*	-.21	-.14
	Baseline_TA_NTO	Placebo_TA_NTO	LowDose_TA_NTO	HighDose_TA_NTO
	ACC	*ACC*	*ACC*	*ACC*
RT	-.16	-.16	-.11	-.11

TA is target-absent condition and TP represents target-present condition. NTC indicates the color non-target condition, NTO is the orientation non-target condition. Asterisks (*) indicate significant Pearson correlations (p < .05)

Means and SEM in the RSVP task

Table. A3.3. Overall and lag-specific means of T1 identification accuracy, T2 identification accuracy, T2|T1 accuracy and temporal integration frequency in the attentional blink task

	Baseline		Placebo		Low Dose		High Dose	
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Overall T1 ACC	70.0	2.4	67.4	3.1	71.0	2.2	67.9	2.9
T1 ACC-Lag1	41.4	3.6	41.0	4.1	41.3	3.3	41.2	3.8
T1 ACC-Lag3	82.7	2.3	78.2	3.3	83.8	2.3	79.4	2.9
T1 ACC-Lag8	86.0	2.0	83.0	3.0	87.8	1.9	83.1	2.7
Overall T2 ACC	65.2	2.6	62.8	3.5	66.2	2.6	63.4	3.2
T2 ACC-Lag1	35.8	3.9	36.6	4.5	36.0	3.9	37.3	4.1
T2 ACC-Lag3	73.2	2.8	69.2	3.9	74.3	3.0	70.1	3.6
T2 ACC-Lag8	86.7	1.9	82.6	3.1	88.2	2.1	82.8	2.8
Overall T2|T1 ACC	76.9	2.5	75.1	3.3	79.0	2.5	78.1	2.5
T2|T1 ACCLag1	58.9	5.1	61.5	4.8	63.9	4.5	64.7	4.4
T2|T1 ACC-Lag3	80.1	2.2	77.0	3.4	80.9	2.4	78.7	2.7
T2|T1 ACC-Lag8	91.7	1.2	86.9	2.8	92.2	2.7	90.9	1.4
Overall Integration	6.1	1.0	5.7	1.0	6.9	1.1	6.1	1.0
Integration-Lag1	16.9	2.6	15.4	2.6	18.2	2.8	16.6	2.6
Integration-Lag3	1.2	.3	1.3	.4	1.9	.6	1.2	.4
Integration-Lag8	0.3	.1	.3	.1	.4	.2	.4	.2

ACC means accuracy and SEM means standard error of the mean. All means and SEM are presented in percentage values

Mean accuracy, RT, and SEM in the VS task

Table. A3.4. Overall and condition-specific mean accuracies and RT in visual search task

	Baseline		Placebo		Low Dose		High Dose	
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Overall ACC	95.4	.5	95.5	.5	95.2	.6	95.9	.4
TA ACC	96.0	.5	96.1	.5	95.8	.6	96.7	.5
TP ACC	94.8	.6	94.9	.6	94.7	.6	95.2	.5
NTC ACC	94.5	.6	94.9	.6	94.5	.6	95.2	.5
NTO ACC	96.3	.5	96.1	.5	95.9	.5	96.6	.4
TA & NTC ACC	94.8	.7	95.2	.6	94.7	.7	95.8	.6
TA & NTO ACC	97.3	.4	97.0	.5	96.9	.5	97.6	.4
TP & NTC ACC	94.2	.7	94.6	.7	94.3	.6	94.6	.5
TP & NTO ACC	95.4	.6	95.2	.6	95.0	.7	95.7	.4
Overall RT	344.5	6.7	343.6	6.7	334.9	5.2	339.8	6.9
TA RT	350.7	7.3	351.9	7.1	340.6	5.8	347.1	7.5
TP RT	338.2	6.6	335.2	6.8	329.1	5.2	332.1	6.7
NTC RT	352.2	7.2	351.1	7.1	342.5	5.5	347.3	7.3
NTO RT	336.7	6.3	336.0	6.4	327.2	5.0	331.9	6.5
TA & NTC RT	363.1	7.9	363.9	7.7	351.9	6.1	357.3	7.9
TA & NTO RT	338.3	6.9	339.9	6.6	329.3	5.7	336.8	7.2
TP & NTC RT	341.3	6.9	338.4	6.9	333.2	5.3	337.3	7.0
TP & NTO RT	335.2	6.3	332.1	6.7	325.1	5.1	326.8	6.3

ACC indicates accuracy, TA is target-absent condition, and TP represents target-present condition. NTC indicates the color non-target condition, NTO is the orientation non-target condition. SEM means standard error of the mean. Accuracies are reported as percentage values, and RTs are given in milliseconds.

SUMMARIES

English Summary

We investigated whether target identification and temporal integration in rapid serial visual presentation tasks have similar underlying mechanisms or not. Rapid serial visual presentation tasks are used to characterize temporal attention and more generally temporal dynamics of target processing. The task is to report target(s) amidst distractors in a fast stream of visual stimuli. When multiple targets are shown with close temporal proximity, between 100-500 ms, processing of the first target interferes with subsequent ones. That difficulty is expressed in the attentional blink phenomenon (Raymond, Shapiro, & Arnell, 1992). Interestingly, when targets are presented very quickly, in direct succession without any distractors in between, the targets can be identified relatively easily. In such conditions it has also been observed that targets` temporal information may be lost, since observers make many target order errors (Hommel & Akyürek, 2005). This has been attributed to the idea that targets may fall in the same perceptual episode, and are subject to temporal integration (Akyürek et al., 2012).

Here we manipulated both low level target features, as well as the mental state of our participants through dietary supplementation, in order to understand how target processing and temporal integration are related. Specifically, we tested the research questions that are listed below:

1. Whether a change in low-level stimulus features (color/contrast) influences temporal integration and attention (Chapter 2).
2. If Gestalt properties influence the temporal binding of targets and target identification (Chapter 3).
3. If manipulating mental state of participants influence temporal integration and target identification in a similar direction or not (Chapter 4).

In Chapter 2, we tested how featural (color) and non-feaatural (contrast) changes of target pairs influence target identification and temporal integration. Mainly, targets shared the same color/contrast in one condition, while the color or contrast of the target pairs was different in the other condition. Furthermore, temporal proximity of targets was manipulated as targets either followed each other successively (lag 1), or there were two distractors in between targets (lag 3), or seven distractors (lag 8). We observed better target identification and more frequent temporal integration of successive targets when there was a categorical change in target color compared to no change of target color. We explained these outcomes by reduced competition between targets. Consistent with previous work (Akyürek, Köhne, & Schubö 2013), featural dissimilarities increased episodic distinctiveness of the targets, which resulted in better target identification performance. A possible mechanism that explains more frequent integration in the different color condition may be that same-color targets trigger a segregation response opposing the tendency of integrating targets, in an effort to maintain episodic distinctiveness (Wyble, Bowman & Nieuwenstein, 2009). At the same time, the contrast manipulation mainly resulted in high contrast targets masking the low contrast ones regardless of the temporal position of the high contrast target relative to the low contrast target.

In Chapter 3, we investigated the impact of perceptual grouping on target identification and temporal integration by manipulating the Gestalt features of the targets. Perceptually simple, 'good' figures are considered to follow Gestalt rules (e.g., convergence). In one condition, targets formed a good Gestalt together, while targets did not form a good Gestalt in another condition. We used the same manipulation of temporal target proximity, implementing both short and long lags, and including lag 1. Previous work suggested that Gestalt rules should affect early visual processing. For instance, stronger responses to collinear elements compared to random elements in early visual areas have been observed (Altmann, Bulthoff, Kourtzi, 2003; Seghier & Vuilleumier, 2006). In line with these findings, in our behavioral task we also observed benefits of Gestalt properties on both target identification and temporal integration, indicating that perceptual grouping has similar, early effects on target identification and temporal integration.

Last but not least, in Chapter 4 we manipulated the mental state of participants via cocoa flavanols. Cocoa flavanols increase nitric oxide synthesis in the body and brain (Fisher et al., 2003). As a result, blood flow in brain arteries is increased, which may cause facilitated cognitive performance. In addition to studying temporal target processing, we also tested if cocoa flavanols have an effect on spatial attention, in order to have a full picture of how cocoa flavanols influence selective attention overall. Consumption of cocoa flavanols resulted in no effect on target identification and integration in rapid serial visual presentation. However, we found that acute consumption of cocoa flavanols did improve the efficiency of visual search (i.e., spatial attention), which was reflected in reduced reaction times in the experimental condition compared to baseline as well as placebo performance.

In sum, these chapters tested in different but related ways if target identification and temporal integration share similar underlying cognitive mechanisms. Overall, the empirical outcomes in this dissertation suggest that temporal target identification and integration are both influenced by exogenous stimuli properties and by flavanol-induced changes in mental state, and often also in a similar direction, especially at lag 1: (I) Temporal integration and attention both benefit from a categorical change of target colors due to reduced competition between targets. (II) A change in target strength increases temporal target identification but not integration suggesting that compatibility is most vital for integrations in RSVP. (III) Temporal attention and integration are both facilitated when targets are compatible and form a figure with Gestalt properties. (IV) A flavanol-induced change in the mental state did not result in an effect on identification and integration. Of course, the research in this thesis is but a first step towards unraveling the similarities between temporal integration and target identification in rapid serial visual presentation, and many more experiments can still be done to further study this issue. In view of the present results, this would seem to be a fruitful avenue for further research.

Nederlandse Samenvatting

translated from English by

B. van den Berg, R. Nijenkamp, and J. M. Salet

In deze these hebben we gekeken of de processen die ten grondslag liggen aan het identificeren van een stimulus en het temporeel integreren van stimuli hetzelfde zijn in een taak waarbij visuele stimuli kortdurig getoond worden. Deze zogenaamde "Rapid Serial Visual Presentation Task" (RSVP) - ofwel, snelle seriële visuele taak – wordt gebruikt om temporele aandacht, en de temporele dynamiek van het verwerken van target stimuli in het algemeen, te beschrijven. De taak voor de proefpersoon is om een target te detecteren tussen een snel opvolgende serie stimuli. Wanneer meerdere targets snel achter elkaar gepresenteerd worden (tussen 100 en 500 ms) verstoort dit de verwerking van de serieel getoonde stimuli. Deze verstoring staat bekend als de attentional blink (Raymond, Shapiro, & Arnell, 1992). Echter, indien targets heel snel achter elkaar gepresenteerd worden, zonder tussenkomst van overige stimuli, dan treedt dit fenomeen niet open worden de targets relatief eenvoudig gedetecteerd. Dit gaat echter wel ten koste van de temporele informatie van targets (Hommel & Akyürek, 2005). Een mogelijke verklaring voor deze toename in target identificatie is dat de verschillende, kort opeenvolgende targets door middel van temporele integratie op hetzelfde geheugenspoor komen te liggen (Akyürek et al., 2012).

In deze these bestuderen we bovengenoemde processen - target identificatie en temporele integratie van visuele informatie - middels het manipuleren van zowel de visuele eigenschappen van de target stimuli als de mentale toestand van de proefpersonen. De mentale toestand hebben we gemanipuleerd door middel van de inname van cacao flavanolen. De these bevat de volgende kernvragen:

1. Hebben visuele eigenschappen zoals target kleur en contrast een invloed op aandacht en temporele integratie? (Hoofdstuk 2)

2. Hebben Gestalt eigenschappen invloed op de temporele integratie en de detectie van targets ? (Hoofdstuk 3)

3. Heeft het manipuleren van de mentale toestand van proefpersonen een overeenkomend effect op zowel de temporele integratie als de detectie van targets? (Hoofdstuk 4)

In Hoofdstuk 2 hebben we gekeken hoe veranderingen van kenmerkende (kleur) en niet-kenmerkende (contrast) eigenschappen van target paren de identificatie en temporele integratie van targets beïnvloedt. In dit experiment had een target paar dezelfde kleur maar een verschillend contrast of hetzelfde contrast maar verschillend in kleur. Ook werd de temporele structuur van de targets gemanipuleerd; de targets konden direct achter elkaar gepresenteerd worden (lag 1) of bevatte de tussenkomst van twee (lag 3) of zeven (lag 8) andere stimuli. De resultaten toonden aan dat target paren bestaande uit verschillende kleuren vaker temporeel werden geïntegreerd en beter werden geïdentificeerd. Volgens ons kan dit verklaart worden door verminderde competitie tussen stimuli. Deze resultaten zijn consistent met het werk van Akyürek, Köhne, en Schubö (2013). Dit werk suggereert dat de vorming van unieke geheugensporen voor contrasterende stimuli eigenschappen leidt tot verbetering in target identificatie. In tegenstelling, zouden target paren bestaande uit dezelfde kleuren een process in werking kunnen stellen die ervoor zorgt dat de temporele structuur bewaard wordt (Wyble, Bowman & Nieuwenstein, 2009). De resultaten aangaande de contrast manipulatie van de target paren demonstreerde dat de targets met met een hoog contrast de targets met een laag contrast maskeerde, onafhankelijk van de temporele positie van de target met hoog contrast in de stimulus keten relatief aan de target met laag contrast.

In Hoofdstuk 3 onderzochten we de invloed van perceptuele integratie op het identificeren van de target en temporele integratie, door de Gestalt eigenschappen van de target stimulus te manipuleren. Zogenoemde Gestalt stimuli zijn over het algemeen makkelijk te verwerken. In één conditie bestonden de targets uitGestalt stimuli, ende andere conditie vormden de targets geen Gestalt. In beide condities manipuleerden we hoe snel target stimuli elkander opvolgen en hoeveel stimuli er tussen de twee targets werden gepresenteerd(de lags). Eerder werk heeft laten zien dat Gestalt stimuli de vroege verwerking van stimuli beïnvloedt. Een voorbeeld hiervan is de betere visuele verwerking wanneer elementen collineair gepresenteerd worden in vergelijking tot wanneer deze willekeurig georganiseerd gepresenteerd worden (Altmann, Bulthoff, Kourtzi, 2003; Seghier & Vuilleumier, 2006). Overeenkomstig met deze bevindingen, vonden wij ook voordelen van de aanwezigheid van Gestalt eigenschappen; betere identificatie van de target, en meer temporele integratie.

In het laatste, maar zeker niet het minst belangrijke Hoofdstuk 4 manipuleerden we de mentale toestand van de proefpersonen door middel van cacao flavanolen. Deze flavanolen verhogen de synthese van natriumoxide in het lichaam en het brein (Fisher et al., 2003). Als gevolg hiervan bevordert de bloedstroom in de aderen van de hersenen. Dit leidt mogelijk tot de verbetering van cognitie en gedrag. Naast het bestuderen van het effect van deze flavanolen op temporele integratie, onderzochten we ook het effect van flavanolen op spatiële aandacht om een volledig beeld te kunnen krijgen van het effect dat cacao flavanolen hebben op selectieve aandacht in het algemeen. We vonden dat de inname van cacao flavanolen geen invloed had op de detectie van de target, noch op de temporele integratie. Resultaten lieten echter wel zien dat het innemen van cacao flavanolen zoektijden verlaagd, en dus spatiële aandacht verbeterd, ten opzichte van de baseline en de placebo conditie..

Alles bij elkaar genomen onderzoekt deze these of dezelfde cognitieve mechanismen ten grondslag liggen aan target identificatie en temporele integratie. Vanuit een breder perspectief bekeken laten de uitkomsten van deze studies zien dat target identificatie en temporele integratie beïnvloed worden door zowel stimulus specifieke eigenschappen als de verandering in mentale toestand door cacao flavanolen. Dit is met name het geval wanneer target stimuli vlak achter elkaar gepresenteerd worden (lag 1). De these beschrijft de volgende hoofdbevindingen: (I) Door de afname in competitie tussen target stimuli die verschillend van kleur zijn nemen zowel aandacht als temporele integratie toe. (II) Een verandering in het contrast tussen target stimuli verhoogt de identificatie van de target maar niet de temporele integratie, wat suggereert dat compatibiliteit essentieel is voor integratie effecten in RSVP taken. (III) Gestalt stimuli verbeteren zowel de temporele integratie als aandacht. (IV) Cacao flavanolen die invloed hebben op de mentale toestand hebben geen invloed op temporele integratie, noch op identificatie. Het onderzoek in deze these is een eerste stap richting het ontrafelen van de processen temporele integratie end stimulus identificatie. Al zijn de gepresenteerde resultaten verwachtingsvol, voor een meer compleet begrip van deze processen zal er meer onderzoek nodig zijn.

Türkçe Özet

edited by C. Karabay

Hızlı ve sıralı görsel sunum görevinde (rapid serial visual presentation) *zamansal birleştirme* (temporal integration) ve *hedef tanıma*nın altında yatan mekanizmanın benzer olup olmadığını araştırdık. Hızlı ve sıralı görsel sunum görevleri zamansal dikkati ve daha genel olarak hedef tanımanın zamansal dinamiklerini karakterize etmek için kullanılır. Bu görev çeldiricilerin arasında bulunan hedeflerin görsel uyarıcıların hızlı sunumları sırasında rapor edilmesini içerir. Birden fazla hedef zamansal olarak yakın bir süreçte gösterildiğinde (100-500 ms arasında), ilk hedefin işlenmesi daha sonraki hedeflerin işlenmesi engeller. Hedefi tanımlamakta yaşanıla bu zorluk "***dikkat sekmesi***" (attentional blink) fenomeni olarak adlandırılmıştır (Raymond, Shapiro, & Arnell, 1992). Hedefler aralarında çeldirici olmadan çok hızlı bir şekilde (200 ms'den kısa bir süre) sunulduğunda ise ilginç bir şekilde hedef tanıma kolaylıkla yapılabilmektedir. Bu gibi durumlarda hedeflere dair zamansal bilgilerin unutulabileceği hedeflerin sıralamalarının yanlış olarak raporlanması şeklinde gözlemlenmiştir (Hommel & Akyürek, 2005). Bu gözlem hedeflerin aynı algısal episoda düşebileceğine atfedilmiştir, ve zamansal birleştirmenin konusudur (Akyürek et al., 2012).

Bu çalışmada hem düşük seviyeli uyarıcı özellikleri hem de diyet takviyeleri aracılığı ile katılımcıların zihinsel durumları manipüle edilerek bilgi işleme ve zamansal birleştirmenin ilişkisi anlaşılmaya çalışılmıştır. Özellikle aşağıdaki araştırma sorularına cevap aranmıştır:

1. Düşük seviyeli uyarıcı özelliklerindeki (renk/kontrast) bir değişimleme zamansal birleştirme ve zamansal dikkati etkileyip etkilemediği (Bölüm 2).

2. Gestalt kurallarının hedeflerin zamansal birleştirmesi ve tanılanmasında etkisi olup olmadığı (Bölüm 3).

3. Katılımcıların zihinsel durumlarının manipüle edilmesinin zamansal birleştirme ve hedef tanımayı benzer bir şekilde etkileyip etkilemediği (Bölüm 4).

Bölüm 2'de hedef çiftler üzerinde hedeflerin özellikleri olan (renk) ve özelliklerinden olmayan (kontrast) değişimlemelerin hedef tanımlamaya ve zamansal birleştirmeye etkilerini inceledik. Genel olarak bir koşulda hedefler aynı renk ya da kontrasta sahipken diğer koşulda hedeflerin renkleri ya da kontrastları farklıydı. Ek olarak, hedeflerin birbirleri arasındaki zamansal yakınlığı da manipüle edilmiştir: hedefler birbirlerini aralarında çeldirici olmadan takip ettiler (gecikme 1 (lag 1)), aralarında iki tane (gecikme 3) ya da yedi tane (gecikme 8) çeldirici vardı. Gecikme 1 koşulunda hedeflerin özelliklerinden olan renkler farklı olduğunda hedef renk çiftlerinin aynı olduğu koşula göre daha iyi bir hedef tanıma performansı ve daha yüksek oranda zamansal birleştirme gözlemledik. Bu sonuçları hedefler arasındaki rekabetin azalması bağlamanında ele aldık ve açıkladık. Daha önceki çalışmalarla paralel olarak (Akyürek, Köhne, & Schubö 2013), özelliğe dayalı farklılıkların episodik ayırdediliciği artırdına işaret etmiştir ve daha iyi bir hedef tanıma ile sonuçlanmıştır. Farklı renk koşulunda daha fazla zamansal birleştirme gözlemlenmesinin olası mekanizması aynı renk hedeflerin episodik ayırdediciliği sürdürebilmek için (Wyble, Bowman & Nieuwenstein, 2009) hedeflerin birleştirilmiş olarak algılanma yanlılığını engelleyen bir ayırma yanıtı vermesi olabilir. Aynı zamanda kontrast manipülasyonunu genel olarak yüksek kontrastlı hedeflerin düşük kontrastlı hedefleri birbirlerine göre olan zamansal pozisyonlarından bağımsız olarak maskelemesi ile sonuçlanmıştır.

Bölüm 3'de algısal gruplamanın zamansal birleştirme ve hedef tanıma üzerindeki etkisini hedeflerin Gestalt özelliklerini manipüle ederek test ettik. Algısal olarka basit ve "iyi" figürlerin Gestalt kurallarını takip ettiğini varsaydık. Bir koşulda hedefler bereager iyi Gestalt oluştururken diğer koşulda hedefler iyi Gestalt oluşturmadı. Hedeflerin birbirlerine olan göreli zamansal pozisyonu üzerinde gecikme 1'in de dahil olduğu kısa ve uzun gecikmeleri de içeren Bölüm 2'ye benzer bir değişimleme yaptık. Literatür Gestalt kurallarının erken görsel alanlara etki edeceğini önermektedir. Örneğin, rastgele elemetlerle karşılaştırıldığında, doğrusal elementlere erken görsel alanlarda daha güçlü tepki gözlemlenmiştir (Altmann, Bulthoff, Kourtzi, 2003; Seghier & Vuilleumier, 2006). Bu çalışmalarla paralel olarak, Gestalt özelliklerininin hedef tanıma ve zamansal birleştirmeye faydalarını hazırladığımız davranışsal görevde biz de gözlemledik. Bu bulgular algısal gruplamanın zamansal birleştirme ve hedef tanıma üzerinde benzer ve erken etkileri olduğuna işaret eder.

Son olarak, bölüm 4'te katılımcıların zihinsel durumları kakao flavanolları kullanılarak manipüle edilmiştir. Kakafo flavanollari vücut ve beyindeki nitric oxide sentezini artırır ve bunun sonucunda beyindeki damarlardaki kan akım hızı artar (Fisher et al., 2003). Beyin damarlarındaki kan akım hızının bilişsel performansı artırabileceği düşünülmüştür. Zamansal bilgi işlemenin yanında kakao flavanollerinin uzaysal dikkate etkilerine de seçici dikkat hakkında yeterli bilgi sahibi olabilmek için inceledik. Kakao flavanollerinin tüketiminin zamansal hedef tanıma ya da zamansal birleştirme üzerine dair herhangi bir etki gözlemlemedik. Ancak, akut kakao flavanolleri kullanımının görsel arama verimini artırdığını daha düşük tepki süreleri ile gözlemledik (görsel dikkat gibi).

Özetle, bu çalışmada farklı ancak birbirleri ile alakalı yöntemlerle hedef tanıma ve zamansal birleştirmenin benzer bilişsel mekanizmaları paylaşıp paylaşmadıklarını inceledik. Bu tez çalışmasının deneysel bölümleri özellikle gecikme 1 koşulunda uyarıcı ya da flavanol kaynaklı olarak aynı yönde etkilendiğine dair kanıtlar sunmuştur. (I) Zamansal birleştirme ve dikkat hedeflerin renklerindeki kategorik değişimlerden aralarındaki azalan rekabet nedeni ile faydalanmıştır. (II) Hedeflerin güçlerindeki değişim hedeflerin tanınmasını artırırken, zamansal birleştirmeyi etkilememektedir. Bu bulgu hedefler arasındaki uyumun zamansal birleştirmedeki önemine işaret eder. (III) Zamansal dikkat ve birleştirme hem hedefler uyumlu olduğunda hem de Gestalt figürü oluşturduğunda kolaylaşır. (IV) Flavanölce zengin bir içecek nedeni ile oluşan zihinsel durumun tanıma ve birleştirme üzerine etkisi olmamıştır. Bu tezdeki çalışmalar hızlı ve sıralı görsel sunum görevinde zamansal birleştirme fenomeninin ve hedef tanıma görevinin arkasında benzer bilişsel süreçler olduğunu işaret etse de bir sonuca ulaşmak için yeterli değildir ve bu alandaki benzerlikleri anlayabilme sürecindeki ilk basamaklardandır.

Acknowledgments

This PhD thesis would not have been possible without the support of some wonderful people around me. Many thanks to all of them whom were part of this journey. Foremost, I would like to express my deepest gratitude to my day to day advisor Elkan Akyürek for the continuous support of my PhD. I cannot imagine completing this dissertation without your encouragement, guidance, and optimism. Likewise, I would like to thank my promotor Monicque Lorist. Your presence and support were there whenever I needed it, especially towards the completion of this thesis.

I would like to thank the whole Research Group E. Working with all of you was overall a great experience. In particular, I would like to thank Rob, Berry, Michael (for great adventures), Güven (for awesome breaks), my office mates Erik, Edyta (for ignoring my noise and being supportive), and Josh (for very competitive dart games), and other fellow PhD students: Atser, Florian, Jefta, Marlon, Nadine, Nico, Ahmet, Robbert, Sanne, Tineke, and Wisnu. I would like to thank the Minnaar`s group for relaxing Friday evenings: Sebastiaan, Tassos, Elliot, Susie, Maja, and Inka.

I would like to thank my old-friends, Çağrı, Koray, Kerem, Şafak H., Şafak E., Damla, Memet, Oğuz, Sena, Omari, Baver, Hande and the others who stayed in contact with me all these years, and listened to my research stories during my PhD. I am also thankful to the Ministry of National Education and all taxpayers in Turkey for financing my PhD.

Last but not least, I would like to thank my family, especially my parents and brother, Cem for being there whenever I needed it. Finally, I would like to thank my wife, Asel. Thank you for testing each of my pilot studies, and experiencing this PhD adventure with me. Without your support and help, I would never complete my PhD.

Publication List

Karabay, **A.**, & Akyürek, E. G. (2019). Temporal integration and attentional selection of color and contrast target pairs in rapid serial visual presentation. *Acta Psychologica, 196,* 56–69. doi:10.1016/j.actpsy.2019.04.002

Karabay, **A.**, Saija, J. D., Field, D. T., & Akyürek, E. G. (2018). The acute effects of cocoa flavanols on temporal and spatial attention. *Psychopharmacology, 235*(5), 1497–1511. doi:10.1007/s00213-018-4861-4

Karabay, **A.**, & Akyürek, E. G. (2017). The effects of Kanizsa contours on temporal integration and attention in rapid serial visual presentation. *Attention, Perception, & Psychophysics, 79*(6), 1742–1754. doi:10.3758/s13414-017-1333-6