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Adaptive event integration in the missing element task

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ABSTRACT

Evidence for adaptive event integration has previously been provided using the Rapid Serial Visual Presentation (RSVP) task. However, it is not straightforward to generalize this finding to other types of tasks that measure temporal integration, because integration in such tasks is known to vary, depending on the method that is used. This variability has been seen as an indication that integration may result from more than a single type of perceptual persistence, and that different integration tasks may not tap into same type of persistence. Therefore, we investigated whether adaptive control of integration in the RSVP task can be replicated using another technique for measuring temporal integration, which may rely more on low-level mechanisms, namely the dot-array integration or Missing Element Task (MET). As in the RSVP studies, stimulus speed expectancy was presently manipulated. The results indicated that integration performance in the MET was not subject to adaptive control. We argue that this discrepancy with previous RSVP studies can most likely be attributed to a specific difference in the type of persistence underlying task performance. Temporal integration in the MET might rely mostly on visible persistence, while for the RSVP task integration relies more on informational persistence. The present findings suggest that, contrary to informational persistence, visible persistence may not be susceptible to adaptive control.

1. Introduction

The perceptual system is continuously exposed to changing information from the environment. To process such dynamic input reliably and to maintain perceptual continuity, it is necessary to integrate incoming information over time. Experimental results have confirmed that our perceptual system does so: When two pieces of information occur in a short period, they are likely to be perceived as part of the same event or as a single object (Di Lollo, 1980; Eriksen & Collins, 1967; Hogben & Di Lollo, 1974). The process that causes this perceptual phenomenon is known as temporal integration. A kind of persistence is considered to underlie temporal integration (Coltheart, 1980), which can be explained as follows: Because of delays in the on- and offset of the neural activity in response to a stimulus, it continues to be 'visible' for a short period after termination of its physical presence. If a second stimulus appears in this period, its image can overlap and interact with the first one (Efron, 1970a; Eriksen & Collins, 1967; Sperling, 1967).

An important question with regard to temporal integration is whether it is purely driven by the properties, and in particular the presentation speed, of the stimuli in the environment, or whether it might be an adaptive process and under endogenous control. This question has been addressed in a study by Akyürek, Toffanin, and Hommel (2008), who showed that people can indeed adjust their temporal integration window to optimize perception with respect to the expectancy of stimulus speed in a rapid serial visual presentation (RSVP) task.

However, based on the existing body of literature, it is an open question whether such a property of integration that is measured using one technique, in this case RSVP, can also be observed using other techniques, since contradictory findings have been reported for different temporal integration methods in the past (Bowling & Lovegrove, 1981, 1982; Coltheart, 1980; Long, 1980). These differences have been explained by the idea that persistence may be a multi-dimensional concept (Coltheart, 1980; Di Lollo & Dixon, 1992). In the present study, we tested whether adaptive control of temporal integration in RSVP generalizes to another temporal integration task, the missing element task (MET), which might rely on a different dimension of visible persistence.

In the remainder of this section, temporal integration in the context of the RSVP task and the MET will be reviewed. Subsequently, the relationship between these tasks and different types of visible persistence will be discussed in the context of the research question of the current study.

1.1. Temporal integration in RSVP

Akyürek et al. (Akyürek & Hommel, 2005; Hommel & Akyürek, 2005) first studied temporal integration with the RSVP task. In this task, a stream of stimuli, which comprise target and distractor items, is presented sequentially to the subject, and at the end of each stream the participants are asked to report the target items (typically two), which

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have been inserted among the distractors at different positions in time. When a second target follows the first one within 500 ms, the second target can often not be identified, a phenomenon called the Attentional Blink (AB; Raymond, Shapiro, & Arnell, 1992). However, if the second target is presented right after the first target, in the so-called Lag-1 position, the AB typically does not occur and the second target is very likely to be reported correctly. This is referred to as Lag-1 sparing, reflecting the fact that performance is spared from the AB deficit (Potter, Chun, Banks, & Muckenhoupt, 1998; Visser, Bischof, & Di Lollo, 1999).

Importantly, Lag-1 sparing has been related to temporal integration. This relationship was first identified by the observation that although Lag-1 sparing allows frequent identification of both target items, it comes at the cost of a substantial number of order errors, which means that the second target is often reported as the first when people report both targets (Akyürek & Hommel, 2005; Hommel & Akyürek, 2005). This confusion of temporal order of the targets was taken to reflect a loss of temporal information about the individual targets, and attributed to a unified perception or temporal integration of the two targets (Akyürek et al., 2012, 2008; Hommel & Akyürek, 2005). This notion of unified perception is broadly compatible with previous ideas about how attentional episodes might envelop two successive targets, but more strongly predicts a merger of the targets in terms of identity and timing. In attentional terms, it has long been thought that when the second target immediately follows the first one, it enters the same attentional window because of a "sluggish" closing of the gate of the attentional window (Potter, Staub, & O'Connor, 2002), and as such both targets are processed in a single episodic trace (Shapiro, Raymond, & Arnell, 1994; Visser et al., 1999).

To measure adaptive control of temporal integration, Akyürek et al. (2008) used the frequency of order errors at Lag-1 as a measure of temporal integration and then manipulated the expectation of the participants about the presentation speed in the upcoming trials in a standard RSVP task. In order to do that, 80% of RSVP trials in each experimental condition were presented faster or slower than the other 20% of trials in the same condition. In a slow RSVP trial, each item lasted 70 ms, and the interstimulus interval (ISI) lasted 30 ms, while the durations were reversed in the fast trials. Thus, stimulus onset asynchrony (SOA) was kept constant, but the stimuli seemed subjectively quite different in terms of presentation speed. The authors hypothesized that if the participants can adjust their temporal integration window to a slow speed expectancy (i.e., extend it), this should lead to an increased chance of integration of the two targets. As a consequence, more order errors should be made at Lag-1 (and vice versa for fast speed expectancy). Indeed, their behavioral results showed that order errors were more frequent at Lag 1 in the conditions when the trial was fast, and expectancy was slow, thereby providing evidence of control over the length of the integration window. Furthermore, these findings were also replicated and supported by further research that measured ERPs (Akyürek, Riddell, Toffanin, & Hommel, 2007). Additionally, the authors observed modulations of the N2 and P3 components, which were associated with the occurrence of a new event episode, particularly when participants expected slow streams, while they were actually confronted with fast streams.

Furthermore, additional evidence supporting the notion of adaptive control over temporal integration comes from a study about perceptual discrimination (Ossmy et al., 2013). In this study, a difference in mean luminance of one out of two fluctuating discs was used as a visual signal. These signals were embedded in a long noisy stream, which may be conceptually likened to RSVP, and the duration and intensity of the signals were varied across the trials. Observers' expectation of signal duration was manipulated by presenting either predominantly the shortest (150 ms) or the longest (900 ms) signal durations in each given experimental session. The researchers hypothesized that observers integrate the increasing luminance of the discs and respond when the luminance difference between two discs surpasses a certain decision threshold. The results of the study showed that the subjects detected the shortest signals better in the session with predominantly short duration signals than in the session with predominantly long duration signals, whereas it was the other way around for the longest signals. Their study indicated that people switched their integration time constant towards the predominant duration of the signal in the session, demonstrating that the perceptual system is flexible to changing the integration time scale dependent on expectation.

1.2. *Integration in the missing element task*

Rather than RSVP, one of the most common tasks used to study temporal integration is the dot-array integration task, also known as the MET (Akyürek, Schubö, & Hommel, 2010; Di Lollo, 1977, 1980, 1983; Di Lollo, Clark, & Hogben, 1988; Di Lollo, Hogben, & Dixon, 1994; Di Lollo & Wilson, 1978; Groner, Bischof, & Di Lollo, 1988; Hogben & Di Lollo, 1974). In the MET, the observers are supposed to integrate information across sequentially presented stimuli to perform well, whereas the opposite is true in RSVP (where observers are trying to individuate targets, not join them). The MET consists of two subsequent brief presentations of displays, which are typically made from 25 dots or squares. Twelve non-overlapping locations in a 5 × 5 matrix are plotted in each display, therefore 24 out of 25 matrix locations are presented and one location remains empty. The observer is asked to detect the location of the item that has not been presented. The MET is typically seen as a direct measurement of temporal integration, because the task is almost impossible to achieve without a simultaneous perception of the two displays. Therefore, correct identification of the missing element location reflects the integration of the two target components. Across several studies, systematic manipulation of the duration of the displays and the ISI in MET have shown that increasing duration of stimulus and ISI reduced the chance of joined perception (Di Lollo & Wilson, 1978; Hogben & Di Lollo, 1974). Thus, persistence time seems to decrease as the duration of stimuli increases, and total persistence time was estimated to be about 130 ms, starting at the onset of the stimulus (Coltheart, 1980; Di Lollo, 1980).

1.3. *Types of persistence*

The most significant contradictory finding between the different tasks, used to study temporal integration, concerns the inverse relationship between the rate of integration (persistence) and target duration and luminance that has been typically observed in the MET (Di Lollo, 1980; Di Lollo & Wilson, 1978; Efron, 1970a, 1970b; Hogben & Di Lollo, 1974; Long & Sakiti, 1981). This effect does not seem to generalize, as other integration methods have failed to report it (Irwin & Brown, 1987; Yemons & Irwin, 1985). This and other inconsistent outcomes between different methods brought forward an idea that persistence might have multiple components, which are differentially taxed by the various tasks used to measure integration. At least two subcategories of persistence, visible and informational persistence, have been suggested (Coltheart, 1980; Hawkins & Shulman, 1979; Long, 1982).Visible persistence is seen as an initial stage of perceptual processing, in which the target stimulus remains visibly present after its physical offset. During visible persistence, stimulus information is precategorical, energy-dependent and more susceptible to decay, which are typical features for low-level aspects of perception. In informational persistence, by contrast, the target stimulus might no longer be visible but visual properties of the stimulus can still be available for a longer period, relative to visible persistence. During informational persistence, some stimulus information is post-categorical and can be stored in a more durable form (Di Lollo & Dixon, 1988, 1992; Irwin & Yeomans, 1986; Yemons & Irwin, 1985).

Furthermore, another factor to distinguish the two types of persistence is the time it takes for memory traces to start to decay, because both of them show different decay functions (Di Lollo & Dixon, 1988; Loftus & Hanna, 1989; Long, 1982). Visible persistence starts to decay just after the onset of the stimulus display and has a fixed duration. Consequently, the time available for persistence decreases as stimulus duration increases, and this produces an inverse relation between stimulus duration and persistence (Coltheart, 1980). On the other hand, informational persistence begins after the termination of stimulus display, and can last a couple hundred milliseconds. It is usually either unaffected or positively affected by stimulus duration and intensity (Hawkins & Shulman, 1979; Loftus, Duncan, & Gehrig, 1992; Long & Sakiti, 1980, 1981).

As mentioned, the two concepts of persistence are thought to differentiate between different experimental methods, because each task might require different levels of perceptual processing due to the different physical characteristics of the target stimuli. For example, the MET is assumed to predominantly reflect aspects of visible persistence, while the partial report technique, which is another traditional method used to measure integration, is seen to better represent informational persistence (Di Lollo & Dixon, 1988; Loftus & Irwin, 1998). The partial report technique comprises the brief presentation of a stimulus array, and a following probe that indicates which part of the array should be reported by the participant. The participant is then expected to identify the probed items from memory.

Di Lollo and Dixon (1988) proposed an important distinction between the two techniques that may relate to the two forms of persistence. They argued that the two tasks depend on different degrees of spatial information. Successful performance in the MET demands reliable spatial information, which decays more rapidly in memory trace. By contrast, partial report tasks require the subject to recall exclusively the identity of items, and despite the fact that the location of the items in the memory display is also critical to correctly report the probed items, it is less spatially demanding than the MET. At the very least, spatial information in partial report tasks can be maintained more abstractly (e.g., as upper, middle or lower rows) in memory. Moreover, some studies demonstrated that most of the errors made by participants in partial report experiments are location errors (Long, 1980; Townsend, 1973; Yemons & Irwin, 1985), which means that participants reported items in different rows or columns from the array display than were probed. This finding indicated that people would be able to maintain the identities of the presented items longer than their spatial coordinates, corresponding to informational and visible persistence, respectively.

1.4. *The present study*

Considering the physical properties of stimuli used in the abovementioned methods, it is reasonable to assume that the kind of information required in RSVP tasks might be more similar to the traditional partial report method than to the MET. First, because RSVP task is comparatively slower than the MET. Second, because the MET is mediated by pre-categorical information and low-level processes, while the outcome of the partial report method depends on more post-categorical and symbolic aspects of information processing, which is similarly the case for the RSVP task. Compared to the MET, the RSVP task might thus tap more into what has been termed informational persistence, rather than visible persistence (Coltheart, 1980; Di Lollo, 1980; Loftus & Irwin, 1998). In view of this potential difference between the types of persistence that the MET and RSVP task rely on, the present study aimed to investigate whether the previously observed endogenous control of temporal integration in RSVP can be generalized, and in particular whether it can also be exercised in the MET. Therefore, we hypothesized that adaptive control is not only limited to a single aspect of temporal integration if it can be performed also in the MET.

2. Experiment 1

Experiment 1 was a conceptual adaptation of the RSVP experiment performed by Akyürek et al. (2008), which was described in the introduction. We primarily adapted the method to use the MET instead of the RSVP task. Similar to the RSVP experiment, we performed our experiment using two speed expectancy conditions: fast and slow. In the fast condition, 75% of the trials featured a relatively short duration of 50 ms for the stimulus display, while 25% featured an 80 ms duration. In the slow condition, 75% of the trials featured a relatively long duration of 110 ms, and 25% featured an 80 ms duration. Therefore, trials with the duration of 80 ms appeared as either faster or slower than the rest (i.e., the large majority) of the trials. We hypothesized that if global task expectancy can modulate the time window of integration, participants will perform differently on trials that are presented at the same actual speed but with a different expectancy about that presentation speed.

2.1. *Methods*

2.1.1. *Participants*

Twenty-one students (six male) from the University of Groningen took part in this experiment in return for course credits (mean age = 20.7, range = 17–32). The study was conducted in accordance with the Declaration of Helsinki (2008) and had ethical approval from the Ethical Committee Psychology (approval number 17090-S-NE). All participants provided written consent before the experiment commenced and they were unaware of the purpose of the study. Each participant reported normal or corrected to normal visual acuity.

2.1.2. *Apparatus and stimuli*

The experiment was programmed in and executed using E-Prime Professional 2.0.10 (Psychology Software Tools), on standard desktop computers that were running the Microsoft Windows 7 operating system. The 19” CRT screens of the computers were set at a refresh rate of 100 Hz with a resolution of 800 by 600 pixels in 16-bit color. Each participant was seated individually in a sound-attenuated room with dimmed lighting. The screen was placed at approximately 60 cm viewing distance and responses were collected via a standard mouse. Experimental stimuli consisted of 25 black squares, which were arranged in a five by five grid.

Stimuli's dimension were as follows: Each square was 0.48° by 0.48° of visual angle (10 by 10 pixels in size), and centered inside invisible square fields subtending 0.97° by 0.97° of visual angle (20 by 20 pixels). The total grid's width and height subtended 4.84° of visual angle (100 by 100 pixels), and there was thus a gap of 0.48° by 0.48° of visual angle (10 pixels) between neighboring squares. A white background was maintained throughout the experiment.

2.1.3. *Procedure*

The experiment was divided into four blocks, each consisting of 160 trials, and divided in two experimental conditions (Slow and Fast speed expectation). Two of the four blocks comprised the fast condition and other two blocks comprised the slow condition. The order of the blocks was counterbalanced between subjects. In order to create the speed expectation conditions, 75% of trials were presented relatively slower (110 ms) or faster (50 ms) than the remaining 25% trials, depending on the experimental condition. These 25% of trials were presented for 80 ms in both conditions. The experiment started with a practice block of 24 trials (omitted from analysis), and then continued with the experimental blocks (Fig. 1). Trials within blocks continued without interruption, but at the end of each block participants were able to take a break. They could continue to the next block whenever they wished by pressing the right mouse button. Each trial began with a blank screen for 600 ms, followed by two successive target displays. The target stimuli were arranged in a grid consisting of 25 invisible square frames. In the first stimulus display 12 black squares appeared within the grid, their locations chosen randomly on each trial. After a brief 10 ms gap, another 12 squares, again chosen randomly from the remaining 13

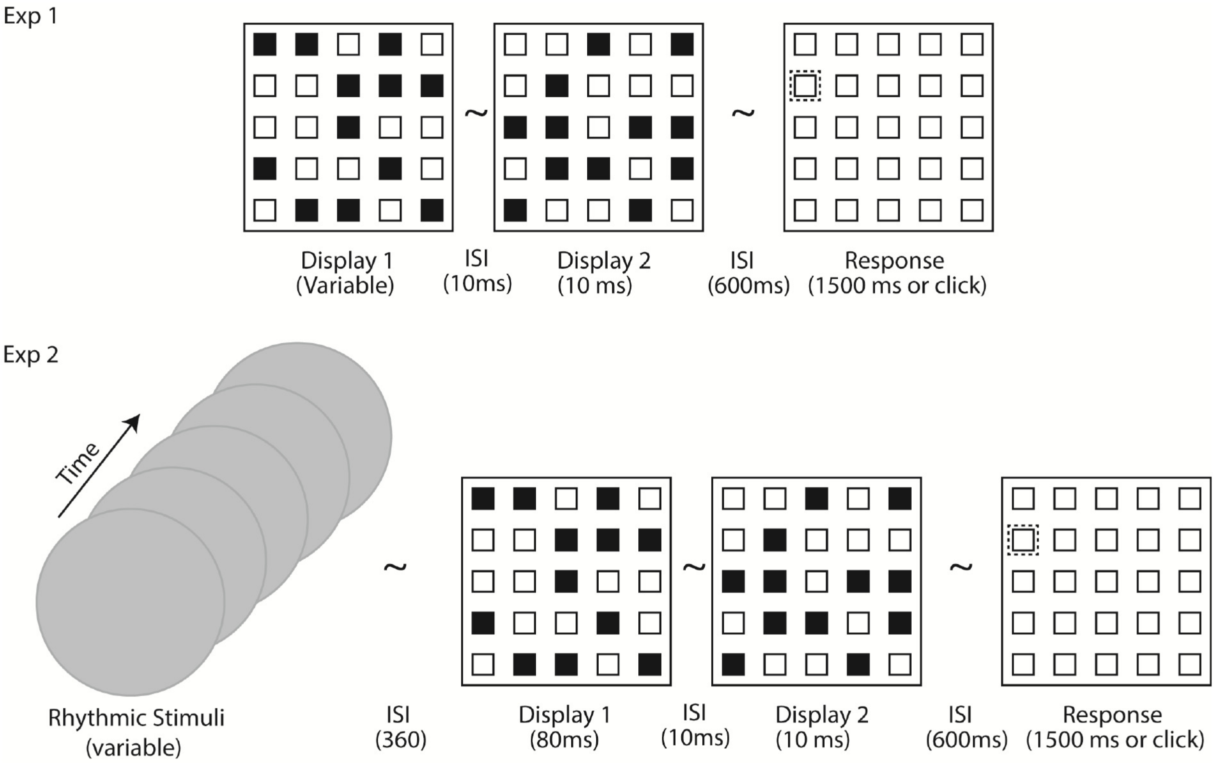

Fig. 1. Schematic representation of the display sequences in the experiments. In experiment 1, the first target display had a variable duration of 80 ms and either 50 ms or 110 ms, dependent on experimental condition. The second target display and the inter stimulus intervals (ISIs) had a duration of 10 ms. In Experiment 2 the same target displays were used but the first target display always lasted 80 ms. In Experiment 2A sixteen sequential light gray circles with a duration of 90 ms (slow condition) or 30 ms (fast condition), and an ISI of 30 ms preceded the target stimuli. In Experiment 2B fourteen sequential light gray circles were used; this sequence was sometimes presented in rhythmic fashion and sometimes presented in an arrhythmic fashion. In the rhythmic condition, the duration of the circles was 120 ms, while in the arrhythmic condition the duration was variable, but of the same average duration. The ISI between circles was 40 ms in both conditions.

locations in the grid, were presented in the second target display, which also lasted for 10 ms. Therefore, a total of 24 out of 25 squares were presented across the two stimulus displays. The task for the participants was to identify the one square location that remained empty in both displays. As is conventional, we considered the correct detection of the missing element location to reflect integration success. After the second set of stimuli, a 600 ms blank interval was presented again. Finally, a response screen appeared, which was terminated either by input from the participant or after 1200 ms had passed.

2.1.4. Data analysis

To assess the overall effect of presentation duration (irrespective of expectations) on performance accuracy a repeated measure analysis of variance (ANOVA) was used, with a single variable, namely the duration of the stimulus display which had three levels (50, 80 and 110 ms). Furthermore, a paired sample *t*-test was used for the analysis of speed expectation, either slow or fast, and which pertained to the 80 ms duration trials only. A significance level of 5% was adopted for all analyses and Greenhouse–Geisser epsilon correction was applied when the test of sphericity was significant.

We also report Bayesian repeated measures ANOVA to analyze the duration of the stimulus display and Bayesian paired sample *t*-tests to compare the two speed expectation conditions. We furthermore computed Bayes factors, which indicate how likely it is for the data to occur under both the null and the alternative hypothesis. The Bayes factor (BF_{10}) represents the ratio of likelihood of data under the alternative hypothesis (H_1) to the likelihood of data under the null hypothesis (H_0). Therefore, a higher value of the Bayes factor BF_{10} indicates the data more likely to occur under H_1 than H_0, and a smaller value of the Bayes factors suggests more evidence for a null hypothesis (Wetzels et al., 2011). To interpret the Bayes factor, we used the classification of evidence in support of the alternative hypothesis developed by Jeffreys (1961).

2.1.5. Data availability

The data are publicly available at the Open Science Framework with the identifier d29nt (osf.io/d29nt/).

2.2. Results

The first analysis tested whether temporal integration performance was affected by duration in general, as would be expected for the MET. The ANOVA revealed that temporal integration performance was strongly affected by duration, $F(1,\ 27) = 49.65$, $MSE = 0.006$, $p < .001$. Average accuracy was highest for the 50 ms duration, at 61.32%, while for the 80 ms and 110 ms duration performance dropped to 48.86% and 41.98% respectively. These results are shown in Fig. 2 as black line and symbols as a function of duration. This pattern was in line with expectations, as it is typical for performance in the MET. However, integration frequency was not affected by the speed expectation condition, $t(20) = -0.279$, $MSE = 0.0197$, $p = .783$. Performance accuracy averaged 48.45% in the fast, and 49.01% in the slow condition (Fig. 2). Additionally, Bayesian analysis provided very strong evidence for a duration effect on temporal integration performance ($BF_{10} > 100$), whereas the Bayesian paired t-test revealed substantial evidence for no effect of speed condition on integration performance ($BF_{10} = 0.24$).

3. Experiment 2A

Modulating the presentation speed of the stimulus displays of the MET showed that integration frequency was unaffected, regardless of

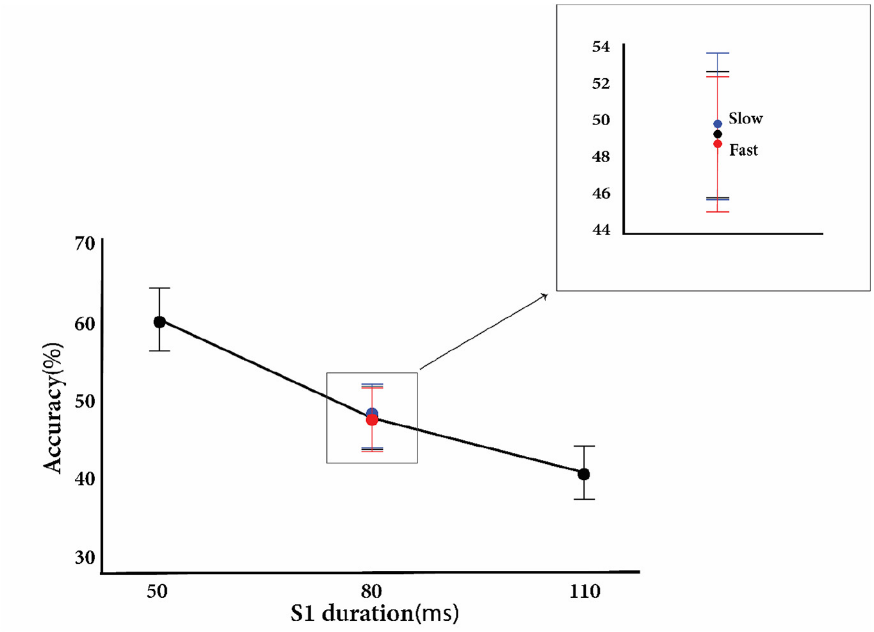

Fig. 2. Percent correct responses in Experiment 1, where black symbols show response accuracy as a function of the duration of the first stimulus display and colored symbols show the percentage of correct responses at 80 ms S1 duration in fast (red) and slow (blue) speed expectancy conditions. The box in the upper right corner shows magnification of 10% around the 80 ms mean. Error bars represent ± one standard error of the mean. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

whether observers were expecting faster or slower trials. One reason for the lack of an adaptive response might be that the stimulus sequences on each trial were too short to induce a robust temporal expectation. In the studies by Akyürek et al. (2007, 2008), a full RSVP was shown on each trial, in which the timing of each distractor item was manipulated together with that of the targets. This more enduring exposure to the temporal manipulation might be particularly effective, because it might create a clear rhythm.

Rhythm is one of the principal ways to induce temporal expectation (Nobre, Correa, & Coull, 2007). It was proposed that regular rhythmic stimuli improves perception in vision by facilitating visual discriminability and modulating early perceptual processing of stimuli that fall in line with the rhythm (Mathewson, Fabiani, Gratton, Beck, & Lleras, 2010; Rohenkohl, Cravo, Wyart, & Nobre, 2012). In the present experiment, we presented rhythmic stimuli before the two successive target displays of the MET to induce a stronger, rhythm-based speed expectancy.

3.1. *Methods*

3.1.1. *Participants*

Twenty new students (six male) participated in the study (mean age 20.4 years, range 18–27). One participant was excluded from analysis because the average number of correct responses was below chance level.

3.1.2. *Apparatus, stimuli, design, and procedure*

The experimental setup was the same as in Experiment 1 with the following exceptions. Experiment 2A consisted of 560 trials, comprising 140 trials for each experimental block. Speed expectation was manipulated by varying the duration of sixteen filled gray circles, whose diameter was 4.84° of visual angle (100 pixels) in size, and which were centered on the screen. The circles were presented sequentially before the target stimuli. The duration of each circle lasted 90 ms in the slow and 30 ms in the fast condition, separated by a 30 ms interval in both conditions. After a 360 ms blank interval (which was intended to limit forward masking effects), the first target stimulus display was presented for 80 ms, which remained unchanged in all trials. The duration of the ISI and second display was fixed at 10 ms as before. A single paired sample *t*-test was carried out on the means, with either a slow or a fast speed expectation as the independent variable.

3.2. *Results*

The paired sample t-test demonstrated that the mean difference between slow and fast speed conditions was not reliable, $t(18) = 0.236$, $MSE = 0.007$, $p = .816$. Bayesian analysis also provided substantial evidence for no difference between the two conditions ($BF_{10} = 0.24$). The average integration frequency was 50.22% in the slow condition and 50.96% in the fast condition. There was thus no discernible effect of the speed of the rhythm on integration frequency.

4. Experiment 2B

In Experiment 2A, we used rhythmic stimuli to modulate the subject's speed expectation, but found no difference on temporal integration performance. One reason for the absence of an effect of the speed of the rhythm on integration frequency might be that both fast and slow rhythms might have facilitated perceptual performance; in both cases there is a consistent temporal pattern present, which the perceptual system might have capitalized on. A stronger comparison might be made if a condition without rhythm was included. Therefore, in Experiment 2B, we investigated whether the presence of a rhythm by itself has an effect on integration performance, and so we investigated the difference between rhythmic and arrhythmic sequences preceding target displays.

4.1. *Methods*

4.1.1. *Participants*

Twenty two new students (eleven male) participated in the study (19.73 years on average, ranging from 18 to 23).

4.1.2. *Apparatus, stimuli, design, and procedure*

The experiment was identical to Experiment 2A, except that speed expectation was now varied between rhythmic and arrhythmic conditions. In rhythmic condition, fourteen filled gray circles were presented before the target stimuli and each of them lasted for 120 ms, with a 40 ms interval in-between. In arrhythmic condition, the duration of each circle varied and was chosen randomly from 40, 60, 80, 120, 160, 180, and 200 ms. The total duration of the circles in each trial was still the same compared to those in the rhythmic condition. The duration of the interval between circles also remained unchanged.

4.2. Results

A paired sample t-test was conducted to compare temporal integration performance in the rhythmic and arrhythmic conditions. The difference between the conditions was not statistically significant, $t(21) = -0.13$, $MSE = 0.023$, $p = .897$. Similar to the previous two experiments, Bayesian result again provided substantial evidence in favor of the two conditions not being significantly different ($\text{BF}_{10} = 0.22$). Average performance was 56.22% in the rhythmic condition and 56.52% in the arrhythmic condition. Thus, rhythmicity also did not seem to modulate integration frequency in the MET.

5. Discussion

The present study was designed to determine whether the adaptive control of temporal integration that was previously observed in the RSVP task can be generalized to integration in the MET. Taking together all of the evidence from the current experiments, it must be concluded that our results are inconsistent with previous findings from experiments using RSVP, and we did not find evidence for adaptive control over temporal integration in the MET. The most plausible explanations for these results will be discussed below.

Previous findings from studies using the MET and partial report designs have coined the idea that visible and informational persistence may each contribute to the temporal integration of information presented in sequential stimuli to a different degree in these tasks. The current outcomes reinforce the idea that the same difference may exist between MET and RSVP tasks. Although temporal integration can be measured using both MET and RSVP, integration in these respective tasks may not be a consequence of the same type of persistence. On this account, we can identify two distinctive features of both tasks which might imply that the different tasks rely on different types of persistence.

The first feature is the total duration from the onset of the first stimulus to the onset of the second stimulus, this is called stimulus-onset asynchrony (SOA). Both RSVP and perceptual discrimination studies have longer SOA than studies using the MET. Di Lollo and Wilson (1978) and Di Lollo, 1980 created a model describing how memory functions when perceiving brief displays, which can explain the two types of persistence. According to this model, a sensory recruiting phase is activated by the stimulus onset and is followed by an interpretation phase, which begins about 100–150 ms after stimulus onset. During the recruiting phase, stimulus features are encoded, which is energy-dependent and sensitive to decay. During the interpretation phase, stimuli are meaning-encoded, which seems to be more immune to decay, but which also has a weaker representation of spatial information compared to the first phase. This model fits well with the results observed in studies using the MET, showing that performance deteriorates sharply when the SOA exceeds about 130 ms (Di Lollo, 1977; Efron, 1970a), which matches the early phase of persistence.

By contrast, persistence time is longer for tasks that measure informational persistence, such as partial report tasks (Dixon, 1985; Irwin & Yeomans, 1986). Given the results of the RSVP studies of Akyürek et al. (2007, 2008), it seems that informational persistence might have had a more important role in these studies, since the total duration of the SOA was either 130 ms (fast condition) or 170 ms (slow condition), both of which are relatively long in terms of persistence. Similarly, signal durations in the decision-making study by Ossmy et al. (2013) also varied from 150 ms to 900 ms, which is significantly longer than the time frame associated with visible persistence. A possible explanation for the presence of an expectancy effect in the RSVP task might thus be that higher-order perceptual mechanisms that encode meaning are involved, because the relevant stimulus information is post-categorical and can be stored in a more durable form (Di Lollo & Dixon, 1988, 1992; Irwin & Yeomans, 1986; Yemons & Irwin, 1985).

The second feature is that the spatial requirements differ in the two tasks. The MET requires the recall of spatial information of visual items, which has been found to decay rapidly, and which is more accurate during visible persistence (Irwin & Yeomans, 1986). However, in RSVP the participant is expected to remember only the identity of two targets and all items are centrally presented at the same location. This type of feature information is more immune to decay and still available during informational persistence. This again suggests that different forms of persistence may underlie performance in these two tasks.

Considering all the information above, it seems reasonable to assume that the difference in terms of adaptive control is related to the difference in persistence that underlies task performance in the MET and RSVP task. Adaptation to differences in expected stimulus speed may only be possible by modulating informational persistence (predominant in RSVP), and observers may not be similarly able to control lower-level visible persistence (predominant in the MET).

Apart from the differences in temporal and featural profile of the stimuli used between the two tasks and forms of persistence, another factor that must be considered is the methodological nature of the experiments, which might led to the lack of a modulation of temporal integration. It is possible that the sequence of stimuli in the current METs were not sufficiently compelling to produce speed adaptation. We tried to overcome this problem in experiments 2A and 2B by presenting a similar number of rhythmic gray circles as there were items in the RSVP task. Nonetheless, in RSVP tasks, two targets are inserted among a stream of distractors with the same duration and ISI as the targets. The ‘targets’ in the current MET were presented 360 ms after the circle sequence, in order to avoid masking-related confounds. The period elapsing between the sequence of the circles and the targets may have caused any possible rhythm adaption to decay, thereby weakening the expectancy of the stimulus speed. Thus, a speed adaptation that might have been induced during the circle sequence might have been lost when the target displays finally arrived. It must be noted, however, that the delay between the inducing circles and the target displays was not prohibitively long, and it might thus be debated whether there was actually sufficient time for the hypothesized decay to take place.

In conclusion, the current study does not provide evidence for the idea that the kind of adaptive control of temporal integration that was previously observed in RSVP tasks is also possible using the MET. There are several possible explanations for why the two tasks were differently affected by expectancy. As alluded to before, one reason may be that the MET requires the observers to perceptually merge the displays to find the missing element, while this is not required, and even a hindrance to performance, in the RSVP task. Nevertheless, we propose that the discrepancy between these tasks arises because they measure different forms of temporal integration, namely visible persistence in the MET and informational persistence in the RSVP task, and that only the latter is amenable to adaptive control. Further converging evidence, possibly based on another method of measuring informational persistence, such as partial report, could be useful to further substantiate and generalize the current account. In addition to that, another direction for future research to confirm and strengthen the present conclusions might be to apply and compare the two methods of RSVP and MET within the same group of participants.

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