The influence of regularities on temporal order judgments

Sanne Haverkort
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Major: Cognitive and Neurobiological Psychology
Author: Sanne Haverkort, 3869814
Advisor: Stefan van der Stigchel
Second graded: Rosalie Iemhoff
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Introduction

The world we live in contains an overwhelming amount of objects and events that all compete for our visual awareness. There is an information overload (Broadbent, 1958). To deal with this information overload we developed mechanisms to guide our attention and to select relevant information (Chun, 2000). What usually helps us is that the environment is highly structured and that there are certain regularities (Zhao, Al-Aidroos, & Turk-Brown, 2013). Using these regularities through statistical learning helps us in guiding our attention to relevant object and to interact with the environment (Fiser & Asling, 2001; Turk-Browne, Scholl, Chun, & Johnson, 2010). Our preference for regularities is not stimulus driven, it reflects learning that happened over time and is based on internal representations of prior experiences (Zhao et al., 2013). This statistical learning happens without our awareness and can occur incidentally during tasks even when it is not required by the task (Turk-Brown et al., 2010; Zhao, Ngo, McKendrick, & Turk-Browne, 2011).

One study by Zhao and colleagues (2013) clearly shows that people attend more towards a structured stream than to a stream of random stimuli. Measuring the time it took participants to notice the target surrounded by distractors in a structured stream compared to a random stream showed that the reaction time was shorter when the target was shown in the structured stream. However, when asked at the end, participants were not aware of the structure in one of the streams. This shows that regularities are learned implicitly and that regularities implicitly guide our attention. So far it has been acknowledged that attention can be stimulus driven or goal directed (Chun, Golomb, & Turk-Browne, 2011**;** Pashler, Johnston, & Ruthruff, 2001). Stimulus driven attention refers to the fact that attention can be driven by salient stimuli, such as an abrupt onset (Yantis, & Jonides, 1984), unique features (Theeuwes, 1992) and novelty (Johnston, Hawley, Plew, Elliott, & DeWitt, 1990). Goal directed attention is attention driven by internal goals or task rules and internal goals enhance the processing of goal relevant stimuli (Theeuwes, 2004). But based on the previously explained experiment (Zhao et. Al., 2013) we have to conclude there is a third factor that guides attention: regularities.

So attention is influenced by regularities, and it has been claimed that attention to a stimulus enhances the speed of processing in the visual system (Casarotti, Michielin, Zorzi, & Umiltà, 2007). That attended stimuli are processed faster than unattended stimuli has been known as prior entry (Titchener, 1908; Posner, Snyder, & Davidson, 1980). Some of the most compelling evidence for prior entry comes from Stelmach and Herdman (1991). They found that perception of temporal order is influenced by attention, providing us with evidence for the assumption that attention influences processing speed (1991). The effects of attention were measured using a temporal order judgment (TOJ) task in which the participants had to report which of two visual stimuli appeared first. They found that when the stimuli were presented synchronously, the attended stimuli were perceived to appear before the unattended stimuli (Stelmach, & Herdman, 1991; Shore, Spence, & Klein, 2001). This shows that processing speed is faster for attended stimuli.

As previously explained, regularities guide people's attention towards a specific location based on expectations and performances on temporal order judgment tasks are sensitive to the influence of attention. Based on these two established facts we wondered if it could be that regularities influence the processing speed of stimuli around us. This led to the following question:

"Do regularities based on color and location guide our attention towards specific stimuli based on the expectations formed due to the created regularities?"

To answer this question we conducted an experiment where we expected regularities in the stimuli to influence participants temporal order judgment performance. If correct, this would indicate that processing speed is faster for stimuli that meet expectations based on regularities. To measure this, we tried to manipulated the direction of attention using stimuli regularities, based on color and location, while requiring participants to judge the temporal order of the stimuli. On every trial there appeared two colored circles, one left of fixation and one right of fixation. The TOJ task was to indicate which circle appeared first. By controlling the colors and having one color appear mostly left and one color appear mostly right we tried to manipulate the direction of attention.

We hypothesize that when participants are forced to make a choice about which stimulus was presented first, even when they are presented synchronously, that they will choose the one that meets their expectations based on the color regularities.

Relevance for artificial intelligence

The results of this study are relevant to artificial intelligence because they give us more knowledge on how our brain processes information. This knowledge can help us create more intelligent robots. Since computer scientist attempt to build devices that mimic the complexity of the human brain (Friedenberg, & Silverman, 2012), information about the human brain is very useful in the process of creating more intelligent robots. To be an intelligent robot, it must be an entity that can perceive the environment that it is surrounded by and interact with that environment (Friedenberg, & Silverman, 2012).

At the same time there is an interesting connection between regularities and learning. We want robots to learn things about their environment so they are able to interact with it. It is generally recognized that in humans, regularities are crucial when it comes to learning (Pfeifer, 2007). Human babies create concepts by combining information acquired through different sensory modalities and later on they will be able to recognize objects based on the visual modality alone. That means that they have learned to predict sensory stimulation in other modalities using the information available through the visual modality. To facilitate this learning of sensory patterns it is necessary that the sensory information that will form the patterns contain regularities and recurrent features (Pfeifer, 2007).

This experiment will contribute to our knowledge on how the human brain works and whether or not regularities influence the way we process information which can help us accomplish creating more intelligent robots. The results will also add to our knowledge of the human learning process and how this learning process could be incorporated in the development of more intelligent robots.

Experiment

Therefore the goal of this experiment is to test whether implicitly formed expectations based on regularities, influence the performance on a temporal order judgment task.

Methods

Participants

Ten undergraduates (9 female, 1 male; mean age = 20,9 years) from Utrecht University participated in this experiment and received six euros in return. All participants reported normal visual acuity. The participants were not aware of the purpose of this study.

Stimuli

Based on previous TOJ experiments we used circles (0.60° in diameter) as our stimuli (Hairston et. al., 2006; Neuman, Esselmann & Klotz, 1993). The location of the stimuli was either 120° left of fixation or 120°right of fixation. And the stimuli were presented at varying stimulus onset asynchronies (SOAs). To create a structure that would implicitly guide participants' attention based on regularities, we used color. The four colors used are red, green, blue and yellow. We created regularities by controlling the location of the appearance of certain colors. The red circle was shown mostly on the left side and the green circle mostly on the right. Out of all the times the red colored circle was shown, it appeared on the left side of fixation 75% of the time (360 times). The green circles were mostly shown on the right side, also 360 times (75%). Both the blue circles and yellow circles are equally distributed between the two sides. So the distribution of colors on the left side was as follows: 360 red circles, 120 green circles, 240 blue circles and 240 yellow circles. On the right side there appeared 120 red circles, 360 green circles, 240 blue circles and 240 yellow circles.

Adding up all these number leads to 1920 colored circles (4x480). Given the fact that each trial consisted of two circles, there were 960 trials where the participants had to make a temporal order judgment. That there were so many trials was due to the fact that all trials were counterbalanced.

We called the trials where there was a red circle on the left side left-expected trials and the trials with a green circle on the right side were called right-expected trials. The trials with blue and yellow circles are non-expected trials.

TOJ task

For each trial the onset time of the two circles varied. The SOAs between the two circles varied between -100ms, -40ms, 0ms, 40ms and 100ms. On the -100ms and the -40ms trials, the right circle was presented first. On the 100ms and 40ms trials, the left was first.

The trials with a 0ms SOA were the ones we were most interested in, because on those trials we expected to see an influence on the participants temporal order judgment based on the regularities we created. The 100ms and -100ms trials were used as a reinforcement to keep the participants motivated and to not give up because of the frustration that could arise on the 0ms SOA trials. We also used a 40ms and -40ms SOA to create variability in onset times between the trials so it would not be too noticeable that there was no difference in onset times on part of the trials. We used 40ms because previous studies have shown that people are able to determine the arrival order of stimulus when the separation between the onset times is 40ms (Kanabus, Szelag, Rojek & Pöppel, 2002). Using a SOA of 40ms guarantees that the difference in onset time is visible without making it to easy for the participants.

Procedure

Each subject was tested individually. The participant sat at a table in front of the display in a dark room. The task of the participants was to decide which stimuli appeared first. They were not told that on one fifth of the trials the SOA was 0ms. Even when the stimuli appeared at the same time, they were forced to choose which one appeared first. The responses were given by pressing the leftward or rightward arrow on a standard keyboard. When they thought the circle on the left appeared first they had to press the leftward arrow and the rightward arrow corresponded with the right circle. The response given by the participants (left or right) was recorded for each trial.

There were a few breaks during the experiment where the participants were able to rest their eyes. In total there were three breaks, when they finished a quarter of the experiment, halve and three quarters. When they felt ready to continue they had to press space bar.

After completing the experiment, all participants answered three questions that were written down; whether there was something special they noticed during the experiment, if they thought one color or more colors appeared more often, if yes which one(s) and whether they thought one color or more colors appeared more on a specific site (left or right), if yes which color(s) on which side(s). The purpose of these questions was to see whether they noticed the structure we tried to create.

Results

The averaged responses given by the participants for the TOJ task are shown in Figure 1.

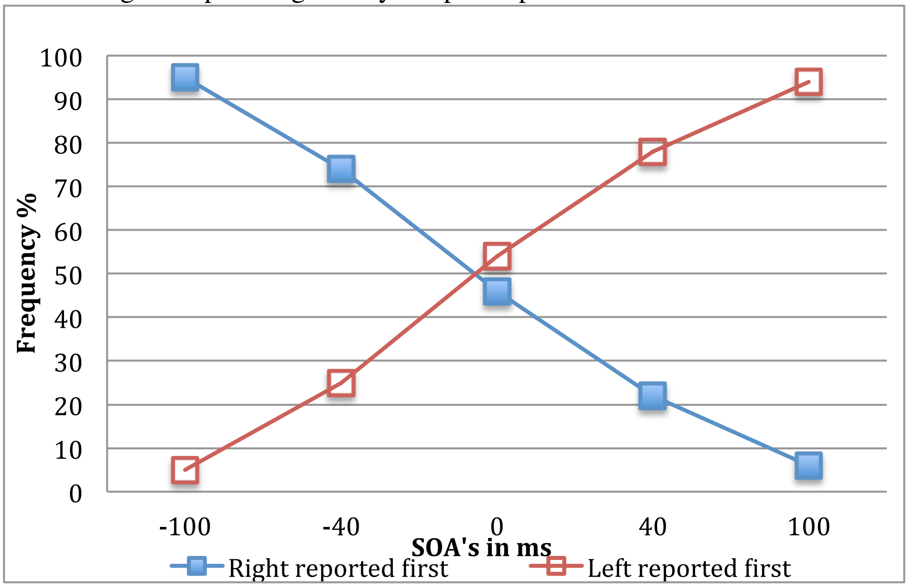

Figure 1. The points represent the answers, averaged across all participants, at the different SOAs. The filled points represent the percentage that the right circle was reported first, the open points represent the left-first reports.

Response accuracy

The mean percent of correct responses (MPCR) was analyzed for the different onset times. The MPCR increased systematically with the increasing onset difference (Figure 2).

The average MPCR for the 40ms trials was 81% (SD = 17.03) and for the -40ms trials it was 74% (SD = 11.98). This is similar to what Kanabus et. al. found (2002) and therefore matched our expectations about the participants performance on the 40ms SOA trials. For the 100ms and -100ms trials the average MPCRs was 94% (SD = 12.31) and 95 (SD = 4.71) respectively.

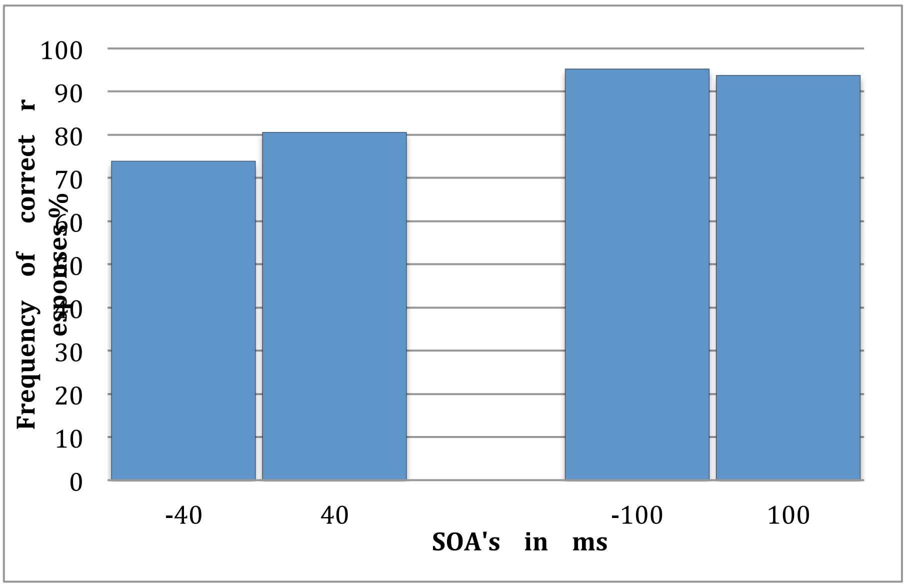

Figure 2. The mean percent of correct responses

Influence of regularities

We further analyzed how the created regularities influenced the participants' judgments. First of all we wanted to make sure the structure was not explicitly noticeable. When looking at the answers participants gave to the questions asked after finishing the experiment, none of the participants reported to have noticed that red was mostly presented on the left side and green mostly on the right side. Therefore, we conclude that participants did not consciously notice the structure we had created.

We used a repeated measure ANOVA with a 3x5 design to measure the effects of timing and regularities. The regularities we tried to create were; not expected, left-expected and right-expected. Timing refers to the different SOA's we used; there were five levels; -100ms, -40ms, 0ms, 40ms and 100ms.

There was a main effect for the stimulus onset asynchrony ($F\ (4{,}135) = 218.29$, $p < .01$). Post hoc testing indicates that there was a significant difference between all the different SOA's, between the -100ms and -40ms SOA ($F(1{,}58) = 53.99$, $p < .01$), the -40ms and 0ms ($F(1{,}58) = 41.10$, $p < .01$), the 0ms and 40ms SOAs ($F(1{,}58) = 36.20$, $p < .01$) and also between the 40ms and 100ms SOAs ($F(1{,}58) = 22.44$, $p < .01$).

There was no significant main effect of the regularities ($F(2{,}135) = 38.59$, $p = .82$). There also was no significant interaction between regularities x SOA $F(8{,}135) = 35.00$, $p = .99$). This indicates that the regularities we created did not influence participants' judgments on the temporal order judgment task.

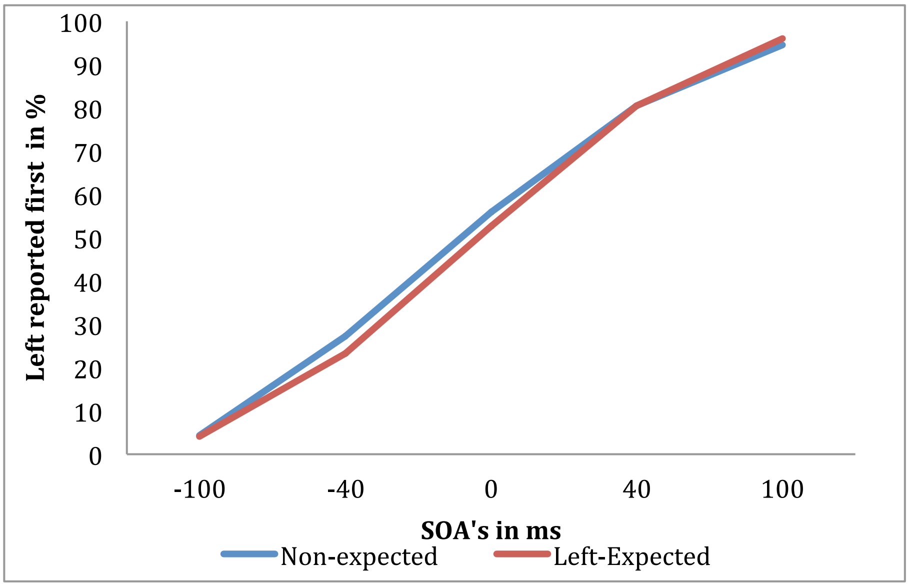

Figure 3. This graphs shows the percentage the participants answered left on the non-expected trials (blue line) compared to the left-expected trials (red line). It shows that the participants did not answer left more often on the left-expected trials.

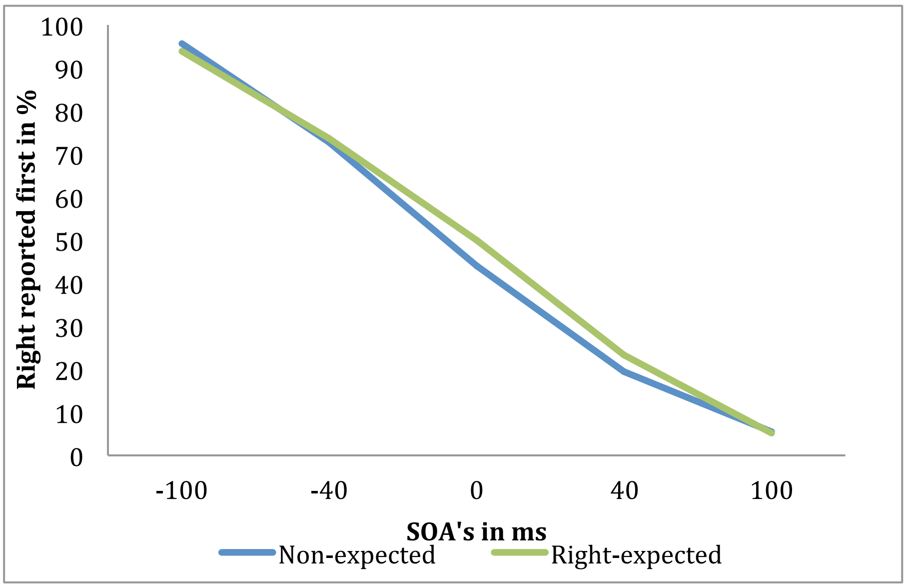

Figure 4. This graphs shows the percentage the participants answered right on the non-expected trials (blue line) compared to the right-expected trials (green line). It shows that the participants did answer right more often on the left-expected trials, however the difference was not significant.

Conclusion

The aim of this study was to investigate whether a presented stimulus is processed faster when it meets implicit expectations that are formed based on regularities. We expected to find that participants, due to the regularities, would answer left more often on the synchronous red expected trials and right on the synchronous green expected trials However, when looking at the condition and timing interaction there was no significant effect of condition for any of the SOAs. Therefore, the regularities we created had no significant influence on the participants' performances on the temporal order judgment task.

Based on these results we have to conclude that the way we tried to guide peoples attention towards a stimulus did not work. The regularities we created did not work as spatial cues on the TOJ task as we had expected.

The fact that the regularities we created did not guide people's attention towards a stimulus could be due to the fact that our study had several limitations. The participants all reported that the task was very hard. Because of this, they might have lost the motivation to keep trying which might have made them answer randomly. But when looking at the mean percent correct response scores, the participants did not make that many mistakes, which seems impossible if choosing randomly. On the synchronous trials there were no overall signs of choosing one side of the other on the synchronous trials they reported left first and green first 54% and 46% respectively, which does not seem random either. That the task was hard does not seem to have influenced their performance when looking at how well they did. It might however, have influenced the guiding towards a specific side that was supposed to happen. Not paying enough attention because it was hard, might have kept the participants from being implicitly guided towards one side.

Also, the fact that we had two expected stimuli might have been too much. The participants were supposed to be guided to the left side by a red circle and to the right side by a green circle. Maybe using two spatial cues that are opposites reduced the effect that structure can have by undoing the guiding that one regularity could have had. Using a structured stream versus an unstructured stream could prevent this from happening (Zhao et. al., 2013).

Based on these results we conclude that our processing speed is not always faster for stimuli that form regularities and that it therefore does not enhance our processing speed in all situations. However, because previous experiments have shown that regularities and expectation can have an influence in some situations, more research is necessary to gain more knowledge on how regularities in stimuli influence our perception and under which circumstances.

References

Broadbent, D. E. (1958). *Perception and communication*. Oxford: Pergamon Press.

Casarotti, M., Michielin, M., Zorzi, M., & Umiltà, C. (2007). Temporal order judgment reveals how number magnitude affects visuospatial attention. *Cognition, 102*(1), 101-117.

Chun, M. M. (2000). Contextual cueing of visual attention. *Trends in Cognitive Sciences*, *4*(5), 170-178.

Chun, M. M., Golomb, J. D., & Turk-Browne, N. B. (2011). A taxonomy of external and internal attention. *Annual Review of Psychology*, *62*, 73–101.

Fiser, J., & Aslin, R. N. (2001). Unsupervised statistical learning of higher-order spatial structures from visual scenes. *Psychological Science*, *12*, 499–504.

Friedenberg, J., & Silverman, G. (2012). *Cognitive science: an introduction to the study of mind (2nd ed)*. Thousand Oaks, CA: Sage.

Hairston, W. D., Hodges, D. A., Burdette, J. H., & Wallace, M. T. (2006). Auditory enhancement of visual temporal order judgment. *Neuroreport*, *17*(8), 791-795.

Johnston, W. A., Hawley, K. J., Plew, S. H., Elliott, J. M., & DeWitt, M. J. (1990). Attention capture by novel stimuli. *Journal of Experimental Psychology: General*, *119*, 397–411.

Kanabus, M., Szelag, E., Rojek, E., & Poppel, E. (2002). Temporal order judgment for auditory and visual stimuli. *Acta Neurobiologiae Experimentalis*, *62*(4), 263-270.'

Pfeifer, R. (2007). Information Theory and Quantification. In M. Lungarella, F. Iida, J. Bongard, & R. Pfeifer (Eds.), *50 Years of Artificial Intelligence: Essays Dedicated to the 50th Anniversary of Artificial Intelligence* (pp. 76 – 133). Berlin: Springer.

Neuman, O., Esselman, U., & Klotz, W. (1993). Differential effects of visual-spatial attention on response latency and temporal-order judgment. *Psychological Research, 56*(1), 26-34.

Pashler, H., Johnston, J., & Ruthruff, E. (2001). Attention and performance. *Annual Review of Psychology*, *52*, 629–651.

Posner, M. I., Snyder, C. R. R., & Davidson, B. J. (1980). Attention and the detection of signals. *Journal of Experimental Psychology: General, 109,* 160-174.

Shore, D. I., Spence, C., & Klein, R. M. (2001). Visual prior entry. *Psychological Science, 12*(3)*,* 205-212.

Stelmach, L. B., & Herdman, C. M. (1991). Directed attention and perception of temporal order. *Journal of Experimental Psychology: Human Perception and Performance*, *17*(2), 539.

Theeuwes, J. (1992). Perceptual selectivity for color and form. *Perception & Psychophysics*, *51*, 599–606.

Theeuwes, J. (2004). Top-down search strategies cannot override attentional capture. *Psychonomic Bulletin & Review*, *11*, 65–70.

Titchener, E. B. (1908). *Lectures on the elementary psychology of feeling and attention*. New York, NY:

MacMillan.

Turk-Browne, N. B., Scholl, B. J., Johnson, M. K., & Chun, M. M. (2010). Implicit perceptual anticipation triggered by statistical learning. *Journal of Neuroscience*, *30*, 11177– 11187.

Ulrich, R. (1987). Threshold models of temporal order judgments evaluated by a ternary response task. *Perception & Psychophysics, 42,* 224-239.

Yantis, S., & Jonides, J. (1984). Abrupt visual onsets and selective attention: Evidence from visual search. *Journal of Experimental Psychology: Human Perception and Performance*, *10*, 601–621.

Zhao, J., Al-Aidroos, N., & Turk-Browne, N. B. (2013). Attention is spontaneously biased toward regularities. *Psychological Science*, *24*(5), 667-677.

Zhao, J., Ngo, N., McKendrick, R., & Turk-Browne, N. B. (2011). Mutual interference between statistical summary perception and statistical learning. *Psychological Science*, *22*, 1212–1219.