The role of binding using an indirect location cue in state-change detection

Adrian Garcia Martin

S3234843

Department of Psychology, University of Groningen

PSB3E-BT15: Bachelor Thesis

Group number: 2122_1b_03

Supervisor: Dr. P.H De Vries

Second evaluator: Dr. W.R van der Mijn

In collaboration with: T. Griffiths, J. I. Houter, V. Piletti and I. Van. Den. Brink

Date: 10.04.2022

Abstract

Change blindness is a cognitive phenomenon described as the failure to detect visual changes in our environment. This cognitive process can throw some light on one of its underlying mechanisms, the process of binding, to hopefully provide potential solutions to the neural binding problem. To do so, we manipulate the process of binding to increase change detection and reduce change blindness. Based on a conceptual network model and the concept of serial binding, a 2x2 repeated measures design was conducted. The participants were instructed to notice changes between pre- and post-change screens, each screen presenting six objects. The experiment made use of an indirect location cue. This experiment investigated two independent variables: the shared object's identity and location. The dependent variables were the correctly identified location of change and the confidence level of the participants response. The experiment's central hypothesis involved an interaction effect: participants would perform better when the object being cued shared its identity with another object in the display and when those objects were placed next to each other. The results support the central hypothesis based on the conceptual network model and the serial binding mechanism.

Keywords: Change blindness, serial binding, conceptual network model

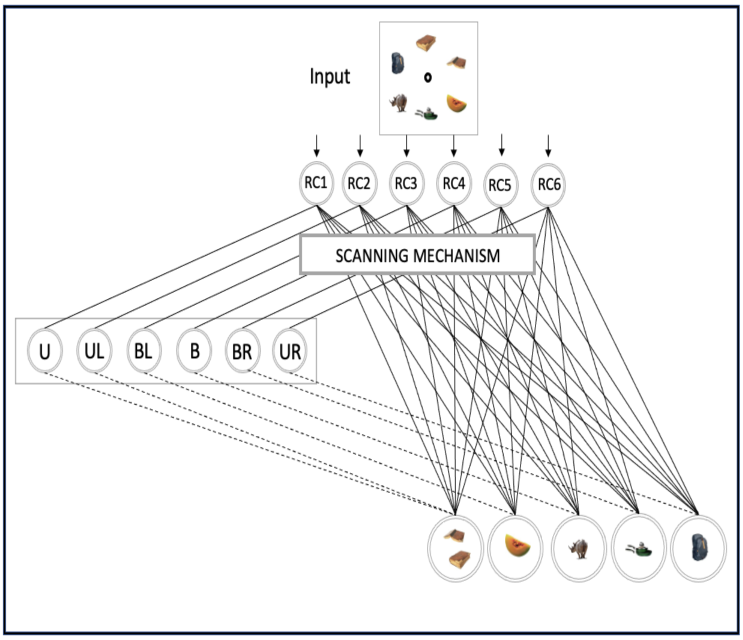
The role of binding using an indirect location cue in state-change detection

Have you always been able to detect your friend's new haircut? Or never miss a road sign change in the speed limit? If the answer is positive, no matter how confident you are, chances are that you are probably mistaken. Lucky are those who have participated in a magic show to acknowledge that even with complete focus on trying to discover the magician's trick, our visions will deceive us more often than not. Up to date, research has presented evidence that people are frequently blind to detect visual changes in pictures as in their surroundings (Simon & Levin, 1998). Those inabilities to detect visual changes are entitled as change blindness. The content of this research paper is based on the previous year bachelor thesis (Braam, 2021; Drake, 2021; Dzhurkov, 2021; Koot, 2021; & Wazny, 2021). Similar to the previous studies, the current paper constructs its theoretical background to the conceptual network model (De Vries, 2004) to further the understanding of binding towards change blindness when multiple objects are presented simultaneously.

To illustrate the phenomenon in a real-world setting, imagine you decide to participate in a martial-arts trial class. As it is your first class, you are part of the beginner group with six people. Each person receives a different set of fighting gloves. While you are drilling techniques with your partner and completely absorbed in the task at hand, one of the persons changes his pair of gloves. Towards the end of the training, you are asked to drill with the person who changed fighting gloves. Would you be able to notice that the person changed the set of gloves? Chances are unlikely. In order to understand why change blindness occurs, it is essential to clarify the underlying processes related to object recognition. Research has demonstrated that different object attributes (for example, the identity and location of an object) are stored in our brain, independently from each other, by different neural systems – called maps (Cooper, 2005). Merging the information from these distinct neural maps is known as binding. Nonetheless, the binding process still holds out an unsolved puzzle in the cognitive paradigm. The point in question of how the brain perceives and displays different representations of objects and location is known as the neural binding problem. Therefore, to have a complete understanding of a complex system such as binding, two different levels of analysis have to be taken into account (de Vries & Dalenoort, 1998). The reason is that even though we seem to have a good comprehension of its relevance on a functional level, binding reflects an issue as it is not yet established how it works on a structural level (Feldman, 2013).

To throw light on these two different levels of analysis: The functional level implies a top-down process of explaining a system in terms of goals. The structural level assumes a bottom-up process based on the mechanisms within a certain system. Regarding binding, the functional level gives a cognitive explanation towards the identity and location of an object in its respective environment (comprehension of the conceptualized object identity connecting to a spatial map, which represents the location of an object). At the structural level, binding is referred to in terms of neural architectures that make up the brain. For example, how neurons from the distinct neural systems are stored in the brain? Moreover, how are these neurons able to accurately communicate with each other? In regards to that process, temporary connections are necessary hence both the location and identity of an object involve separate neural systems as mentioned previously. The temporary connections allow for specific neuron associations without having to store an infinite number of location and identity combinations in our memory (de Vries, 2004). Storing permanent connections between identities and locations would be necessary to remember every single detail of our environment which is structurally almost impossible. If the connection between identities and location would be permanent, our memory would be perfect. Thus, a model in which connections between the identity of an object and its location are temporary is more plausible due to the already stated limitation regarding permanent connections. This describes the importance of binding and its relationship with change blindness because without these connections we would not be able to form new objects representation in our working memory and therefore not accurately perceive and function upon the world around us.

Going one step further, how the process of binding occurs when multiple objects are being presented simultaneously? In an attempt to resolve that point in question, the conceptual network model (CNM) was introduced by de Vries (2004), which is a model that mimics the underlying neural process while being able to assess them functionally (See Figure1).



Legend: *"RC1–RC6: Receptors for visual input; Images within the circle: Memory traces for the objects presented; U, UL, BL B, BR, UR: temporary connection in the spatial map corresponding to the location upper, upper left, upper right, bottom left, bottom right, bottom''. Illustration adapted from de Vries (2004)*

Figure1: The Conceptual Network Model

The conceptual network is based on the Hebbian theory. The idea that “neurons that fire together, wire together” was first initiated by Donald Hebb (1449) to explain how neural circuits are formed and reinforced through repetition. First, neurons communicate by sending electrical signals to other neurons. When two neurons fire together simultaneously, a connection between them is made and stronger their connection becomes, increasing their synaptic efficiency. This neural effect results in the formation of memory traces at the functional level and cell assemblies at the structural level. They are a cluster of neurons that altogether store information about the identity of an object. Taking into account the entire neural circuit of cell assemblies, with all the connections within them would constitute the long-term memory, whereas the cell assemblies being temporarily activated would constitute the working or short-term memory (DeVries, 2004). Following this logic, each cell assembly requires a critical threshold (De Vries 2004) because ‘’once a sufficient number of neurons have become active, the excitation level of the assembly rises autonomously to its maximum. When the activation level exceeds the critical threshold, the corresponding location or identity is assumed to ‘be in short-term memory’ or receives attention’’ (Dalenoort, 1985)

According to Luck and Vogel (2013), the visual working memory actively maintains an amount of visual information to be used for any given task. In order for information to reach short-term memory, the activation level of the cell assembly needs to reach its critical threshold. When it does, the corresponding information becomes ‘’available’’. If the initial external activation is not strong enough, the information will fail to reach the visual working memory. Regarding change blindness, the phenomenon might occur when the cell assembly excitation remains below the critical threshold, not reaching our short-term or working memory.

There has been an ongoing debate on the visual working memory capacity to store information. Luck and Vogel (2013) discriminated against two theories on visual working memory (VWM). The resource continuous theory states that there are not a maximum number of items that can be stored in the VWM but rather a non-specific representation of all the items. On the other hand, the slot-based model was proposed, which suggests that a limited number of items (4) are able to be remembered. In an experiment conducted by Lamme (2003), it was discovered that participants would only remember about four items, the remaining items would be forgotten. This supports the idea of discrete-slot items regarding VWM. The idea of using cues to prevent change blindness was proposed by Lamme (2003), who observed that using a simple location cue (red line pointing from the middle of the screen to the object being cued) to the relevant item before a potential change decreases the probability of change blindness (See Figure2). The purpose of using cues is to draw the participant's attention to specific locations or items to be stored in the short-term or working memory (Lamme, 2003). Therefore, in the previous bachelor studies (Braam, 2021; Drake, 2021, Dzhurkov, 2021; Koot, 2021; Wazny, 2021) they pushed binding to its limit by presenting six objects simultaneously. As the complexity of the computerized task increases drastically by presenting six objects simultaneously, two types of cues were investigated to analyze their effect on change blindness: The identity cue refers to a picture of the item being cued appearing in the middle of the screen. The extended location cue refers to the possible location where a change could happen, (as compared to a simple location where the cue appears at the same location as the upcoming stimulus). A representation of the different types of cues can be seen in Figure 2.

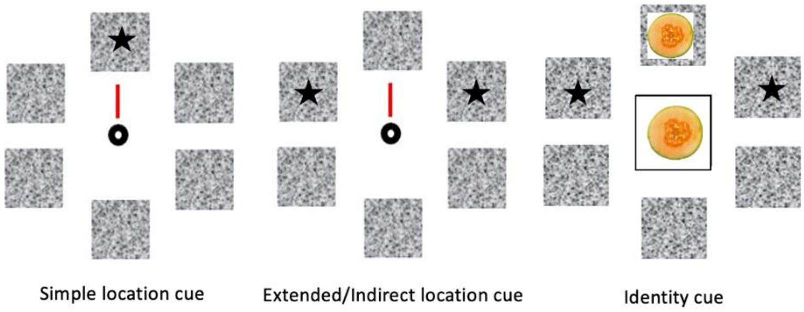


Figure 2: Example of the different types of cues.

The black star indicates where a change could happen

What still remains a mystery, is how the neural representation of the corresponding identity and object location know they belong to each other?

When more than one item is needed to be remembered,'' the respective memory trace and spatial location must be part of the same context, only then, a temporary connection between them will be formed'' (de Vries, 2004). Then, for multiple, simultaneously presented items De Vries (2004) suggested that each memory trace is activated in a sequential manner referring to the notion of a scanning mechanism. Therefore, only one memory trace and one object location will be activated at the same time (See Figure 1). Furthermore, if multiple objects sharing their identity are being presented at once, the memory trace will form several bindings, one per location. On the same hand, De Vries (2004) proposed that if a memory trace receives excitation over more than one temporary connection it will increase the speed of the activation level of the cell assembly's critical threshold to be reached.

De Vries (2004), provided further evidence with regards to the conceptual network and serial binding by means of an identification task experiment. The experiment consisted of successfully detecting letters in a display. To lower the difficulty of the task, De Vries employed a retro location cue to indicate the location of change. The aim of the study was to verify whether manipulating the conceptual network by increasing the number of identical letters (shared object identity) on the screen, would increase the number of temporary connections. It was expected that if a memory trace has more than one temporary connection, the activation level of the corresponding cell assembly has a better chance of reaching its critical threshold and therefore becoming ‘’available’’ in the short-term memory. The study confirmed the hypothesis that increasing the number of identical letters on the screen would increase the performance on the task.

The previous Bachelor studies (Braam, 2021; Drake, 2021, Dzhurkov, 2021; Koot, 2021; Wazny, 2021) followed De Vries pathway by analyzing the interaction between object identity and their location on a change blindness task. As compared to De Vries (2004), the computerized task displayed object images instead of letters. As mentioned before, the experiment pushed the serial binding processes to its limit by presenting 6 objects at once on a screen. Moreover, the screen showed a pre-change display of 6 objects very briefly. It was then followed by a pre and post cue mask before the post-change display. Masking is necessary to inhibit any sort of perceived movement between the pre/post-change display (Simons & Levin, 1997). This way, it forces participants to depend on memory traces rather than their sensorial memory involving the shape, color, or movement of an object. The use of an extended location cue was performed to lower the task difficulty. Somewhat similar to the experiment by De Vries (2004), shared target identity and their location were manipulated in order to find an interaction between the respective factors. Respectively, the target object shared its identity with another object in the display or not. Then, identical objects would either be adjacent to one another or separated by one object. The task of the participant was to indicate whether a change was present next to the target object (either left or right), or if there was no change at all. It was expected that participants would perform better if the target object shares its identity with one of the other objects in the display as well as if those objects are next to each other.

Surprisingly, only Dzurkhov (2021) found the expected significant interaction between distance and shared identity. The reason is, that Wazny (2021) used a different stimulus for his experiment, change-state instead of exemplar changes. Parallelly, Braam (2021) also conducted an experiment with state-changed stimuli. The main difference being the use of an identity cue. Again, the result did not support the main hypothesis regarding shared identity and distance interaction. It was expected that change accuracy performance to be highest when two objects shared their identity and if the two objects were placed next to each other. Showing that state-changes seem to be less easily noticeable than exemplar changes. It also implies that different types of cues might also interfere with the participant's accuracy to detect a change in the display. Two other experiments were conducted using simple location cues with changes-exemplar objects (Drake and Koot, 2021). Although the detection performance increased when the identity of the target object was shared for all the experiments, the effects were not strong enough to suggest an interaction effect between the identity shared object and its location. This is in line with the hypothesis that placing an identical object to the target in the display will lead to a higher accuracy in the change detection scores.

To test whether it was the design complexity that led to the absence of the interaction effect, which was expected because placing an object that shares its identity next to each other should, based on the scanning mechanism, have a priming effect on the memory traces; increasing the speed of the activation level of the cell assembly’s critical threshold to be reached. The current experiment will simplify the design in comparison with the previous studies. Again, this paper will investigate the effects of object identity and location on binding. It is expected that the participants would perform better if the target object shares its identity with one of the other objects in the display, especially if this object is next to the target as a result of the interaction effect between the identity and location of an object. The current experiment will also be using an indirect location cue (as shown in Figure2). The design of the experiment is simplified by always having a change next to the targeted object, either left or right of the object being cued. As the current experiment design is simplified by always having a change, it will be focused on state-changes rather than exemplars, as demonstrated previously state-changes are less likely to be detected than exemplars (Wazny,2021). Nevertheless, every change in the display will undergo a confidence judgment that is expected to be consistent with the performance scores. The purpose of the confidence level is to get an insight into the relationship between the confidence and accuracy of the participant's response. The participants of the previous bachelor thesis described the experiment as being very difficult. We address the difficulty by reducing the number of possible answers from three to two. As in the current experiment there always be a change, we replaced the sensitivity factor from the previous studies with the confidence score in the current experiment.

The aim of this study is to investigate the role of binding towards change detection performance through the manipulation of the location and object's shared identity. The current experiment expects an interaction effect between the shared identity and distance factors meaning that participants should perform better when the object being cued shared its identity with another object in the display and when those objects are placed next to each other. Within the larger study of this research, parallel experiments will be running involving different types of cues: identity and extended identity cues (See Figure2). The difference between the two-identity type of cues is the following: in the extended version, the cue will remain present between the pre-and post-change display whereas in the normal version the cue will disappear in the interval between pre-and post-change display. Presentation times of the screen of the trials will vary between the experiments in order to study its relevance regarding change blindness.

Method

Participant

The total data collection for this experiment was 44 participants. The sample consisted of 31 females and 13 males, resulting in a percentage of 68.9% and 28.9% respectively. The ages varied from 17- 25 years old (M=20, SD= 1.99), with an average of 19.7(SD=1.59) for females and 21.38 (SD=2.39) for males. Only one participant participation was voluntarily (25 years old male) the rest of the participants were a pool of 1st year of psychology students from the University of Groningen. Only the participants whose participation was voluntarily were compensated 2.5€. The faculty of the behavioral Science Ethics board from the University of Groningen has positively evaluated the research plan of this study. There was no risk for the participants as a result of participating in the experiment, nevertheless, the participant had the right to quit at any time.

Stimuli

For this experiment, the stimuli consisted of 24 pairs of images of objects, 48 images in total. The 24 pairs of images were selected from an original file that contained 100 pairs of images, 200 images in total (Konklab, 2020). The pairs included two images of the same object in two different states. For example; a closed and open book as shown in Figure3. Pairs were necessary in order to manipulate the location of the object sharing their identity. Then, we made a selection of categories to make sure that every trial does not display more than one object, or pair, from the same category. Every trial presented 6 objects in a circularly fashion, the 24 pairs used for this experiment were divided into 6 categories (Fruits & vegetables, antiques, Kitchen, Tools, Animals, and Clothing/wearable), distributed over 2 sets. Meaning that the parallel experiments using the same type of cue would use different sets, to control for possible object effects. Each category was made up of 4 pairs of objects. To limit the effect of color and shape on the change detection accuracy, while forming the categories we removed from the selection the pairs that were too easily detectable.

Figure3: Example of state-change pair

Procedure

Prior to the experiment, information regarding the experiment with an informed consent was given to the participant to be completed through Qualtrics (Qualtrics, Provo, UT). After the informed consent, task instructions were given to the participant together with information about personal data collection, participant compensation, and the purpose of the study. The experiment was carried out on a computer through the platform OSWeb (Mathôt, Schreij, & March, 2012). Before starting the experimental trials, participants began with two practice blocks of eight trials each to help them familiarize themselves with the task. During the practice trial, participants receive feedback on their performance. The fixation dot in the middle of the screen would either turn green for a correct answer or red for a false answer. As the participant's familiarity towards the pairs of object and category being selected is out of our control, objects within each category, as well as the object being cued is randomly selected. By doing so, we protect the validity of our results. Then, four experimental blocks were followed by twenty-four trials each, making a total of ninety-six trials. In the experimental trial, participants did not receive feedback on their performance. All the blocks were equally distributed over the four conditions, half of the trials displayed 4 different objects and 2 objects of the same identity yet in different states. Moreover, an object could either share its identity with the target or not. Furthermore, whether the object shares its identity with the object being cued or not, could either be adjacent to one another or not. The objects were displayed on a 6cm radius clock fashion with each object being 1,5cm^2. An illustration of the experimental trial can be seen in Figure 4.

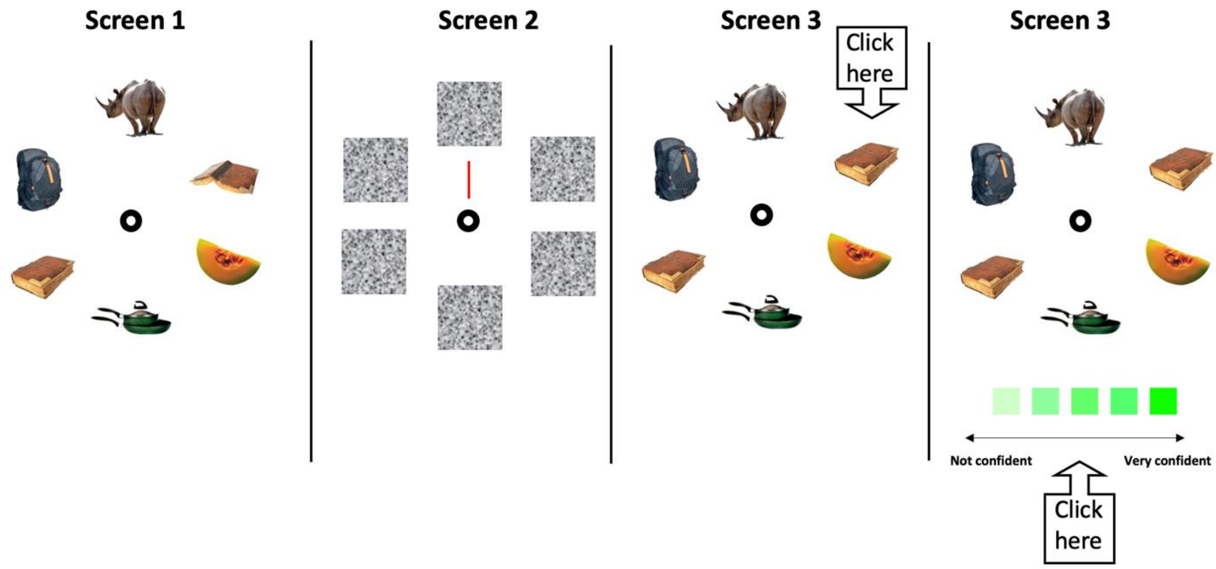


Figure 4: Illustration of experimental trial without feedback

Each trial was made of 3 screens (See Figure 4). Every trial started with a blue square in the middle of the screen. Clicking on the blue square would initiate the trial. It was then followed by the first screen, known as the pre-change display, presenting the 6 stimuli. After a brief interval, the location cue (red line pointing to an object) appears with all the objects being masked in Screen 2. This way, participants would not see the object ‘changing states’ to inhibit any comparisons from pre- to post-change displays. Thus, preventing detection based on sensory memory (movement, shape, and color) and forcing a detection based on working memory. The location cue is followed by another brief interval, after which the post-change display appears on Screen 3. During the post-change display, participants had to indicate the correct location of change which could either be the object to the left or right of the object being cued. After indicating which object changed, participants had to report how confident they were on a sort of 5point-Likert scale. At the end of the experiment, a bar graph was presented to the participant together with an explanation of how they performed. The graph corresponded to their performance accuracy based on whether an object shared its identity with the target and whether these objects were adjacent to each other or not. The duration times for each trial can be found in Table 1.

Pre-trial Screen (blue square)	Until response
Blank screen	500
Reference screen (square)	100
Pre-change display	700
Interval before retro cue	1000
Duration Retro cue	50
Interval after retro cue	200
Post-change display	Until response

Table 1: Presentation times of screens of a trial in ms

Design

The experiment used a 2x2 within-subject design. The independent variables in this experiment were the *identity* of the object and the *distance* of the object. The variable identity contained two levels: the target object shares its identity with another in the display and the target object did not share its identity with another object in the display. The variable distance also contained two levels: The objects sharing identity with the cued object or not, would either be adjacent to one another or be separated by one object. The dependent variables were the *correctly identified location of change* (proportion of correctly answered trials) and the *confidence level* of the participant response.

Figure 5: Examples of the four conditions

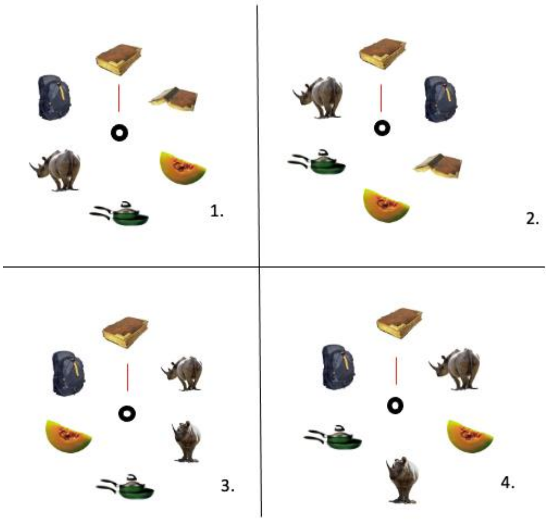


Fig.5 Example for condition 1-4. The target object is indicated by the red line 1=-object shares identity with the target object and is placed adjacent. 2= object shares identity with the target and is not placed adjacent. 3= Identical objects do not share their identity with the target object and are placed adjacent. 4= Identical objects do not share their identity with the target and are not placed adjacent.

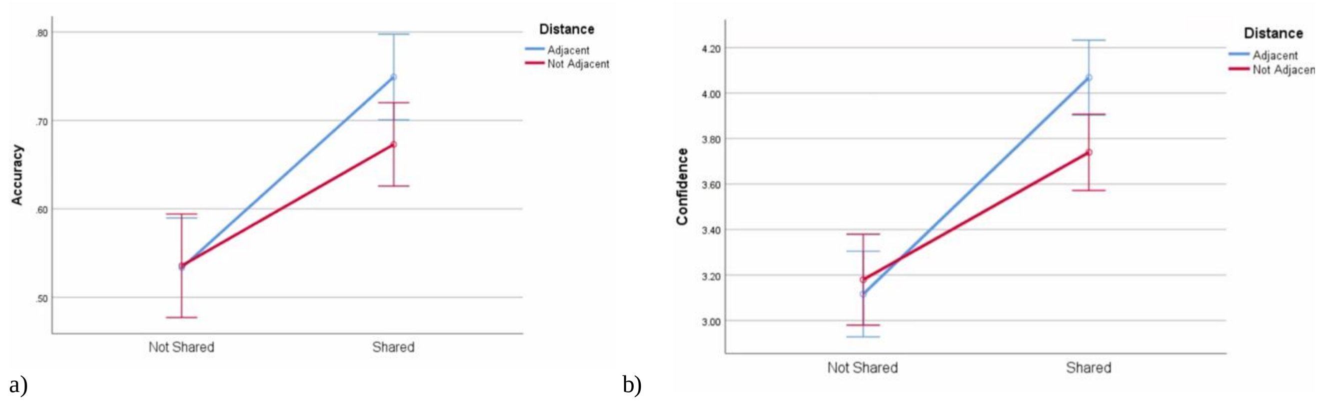
Analysis

The raw data was first collected on the server of OSWeb. In order to provide a repeated measures analysis, we first needed to aggregate and restructure the data via IBM SPSS Statistics (Version 26) predictive analytics software. The analysis was structured in 2 parts. The first part was to investigate the main effects and interaction effect of shared identity and distance on detection change accuracy. To do so, one repeated measures ANOVA and two one-way ANOVAs were conducted. The second part was to investigate the effect of the four conditions on the participant confidence means scores. Again, one repeated measure Anova and two one-way Anovas were done.

Results

For our central hypothesis, we expect change accuracy performance and confidence scores to be superior in the trials under the condition of shared identity and adjacency than to the trials under the condition of non-shared identity. In order words, participants would score higher if an object shared its identity with the object being cued and were next to each other. On the same hand, we expect confidence scores to have the same pattern. It was also expected that the factor distance by itself would not have a significant impact on the participant performance. For the purpose of this research, the interaction effect of shared identity and distance was of principal interest. All the repeated measures ANOVA assumptions were met by the data: The data is approximately normally distributed with no present outliers. Sphericity is met by definition due to each independent variable having two levels only.

In accordance with our main hypothesis, the interaction effect between shared identity and distance was found to be significant for the accuracy analysis at F(1,43) = 11.198, p = 0,002, , η_p^2 = 0.207. (See Figure 6a)



a) b)

Figure6: The relationship between the shared identity and distance factors: a) Detection accuracy, b) Confidence scores. Error bars stand for the 95% confidence intervals.

To verify if the interaction effects are indeed consistent with the hypothesis, two one-way ANOVA were conducted. The one-way ANOVA which investigated the shared conditions distance (adjacent vs not-adjacent) presented a significant difference at $F(1,43) = 16.380$, $p < 0.001$, $\eta_p^2 = 0.276$. For the Shared condition, distance (adjacent vs not-adjacent), participant did better in the adjacency condition (M=0.749, SD=0.16; 95% CI [0.701,0.798], SE=0.024) than they did the not adjacent condition (M=0.673, SD= 0.155; 95% CI [0.626, 0.720],SE=0.023), which aligns with our first hypothesis that shared identity and distance interaction result in a higher correct change detection. These results also support our second hypothesis, sharing identity with another object will result in higher change detection

Then, another one-way ANOVA investigated the Not-Shared condition, distance (adjacent or not-adjacent). We did not find a significant difference at $F(1,43)=0,014$, $p=0.906$, $\eta_p^2 > 0.001$. This time, participant did slightly worse in the adjacent condition (M=0.533, SD=0.186; 95% CI [0.477,0.590], SE=0.028), as compared to the non-adjacent condition (M=0.536, SD= 0.192; 95% CI [0.477,0.594],SE=0.029). This result supports our third hypothesis, the distance between two shared identities other than the target, will not produce higher detection performances.

Furthermore, the main effect for shared identity was also significant at $F(1,43) = 72.280$, $p < .001$, $\eta_p^2 = 0.627$. Participant did better in the shared condition (M=0.711, 95% CI [0.667,0.755], SE= 0.022) as compared to the non-shared condition (M=0.534, 95% CI [0.481,0588], SE= 0.027). Finally, the main effect for distance was also significant at $F(1,43) = 5.429$, $p = 0.025$, $\eta_p^2 = 0.112$. Participants did better in the adjacent condition (M=0.641, 95% CI [0.596,0.687], SE= 0.023) as compared to the non-adjacent condition (M=0.604, 95% [0.556,0.653], SE= 0.024).

Confidence

It is expected that the confidence scores of participants follow the same pattern as their performance scores. For example, if the shared identity object adjacent to the target object produces the highest performances, confidence scores should follow the same pattern.
As expected, we again find a significant interaction effect between shared identity and distance at $F(1,43)=31.520$, $p>0.001$, $\eta_p^2=0.423$ (See Figure 6b).

Again, two one-way ANOVA were conducted to verify the consistency of the interaction effect with the hypothesis.

The one-way ANOVA which investigated the shared condition, distance (adjacent or not-adjacent), found a significant difference at $F(1,43)=31.861$, $p>0.001$, $\eta_p^2 = 0.426$. For the Shared condition, distance (adjacent vs not-adjacent), participants did better in the adjacency condition (M=4.068, SD=0.542; 95% CI [3.903, 4.233], SE=0.082) than they did the not adjacent condition (M=3,739 SD= 0.552; 95% CI [3.572, 3.907],SE=0.083), which aligns with our first hypothesis that performance of change detection will be higher if shared identity is adjacent to the target and therefore confidence score would follow the same pattern. These results also support our second hypothesis that sharing identity with another object will result in higher confidence scores.

Then, another ANOVA investigated the Not-Shared condition, distance (adjacent vs not-adjacent). We did not find a significant difference at $F(1,43)=1.756$, $p=0.192$, $\eta_p^2 = 0.039$. This time, participants did slightly worse in the adjacent condition (M=3.116, SD=0.619; 95% CI [2.928 ,3.304], SE=0.093), in comparison to the non-adjacent condition (M=3.179, SD= 0.658; 95% CI [2.979 ,3.379],SE=0.099) These findings support our third hypothesis that distance between two shared identity objects not related with the targeted object does not influence confidence scores.

Furthermore, the main effect for shared identity was also significant at $F(1,43)=116.890$, $p>0.001$, $\eta p2 = 0.731$. Participant confidence score were higher in the shared condition (M=3.904, 95% CI [3.748,4.059], SE= 0.077) as compared to the non-shared condition (M=3.147, 95% CI [2.960,3.336], SE=0.093). Finally, the main effect for distance was also significant at $F(1,43)=10.884$, $p=0.002$, $\eta p2 = 0.202$. Participant's confidence scores were higher in the Adjacent condition (M=3.592, 95% CI [3.437,3.747), SE= 0.077) as compared to the non-Adjacent condition (M=3.459, 95% CI [3.290,3.629], SE=0.084)

Discussion

At the basis of the experiment, it was expected that detection performances would improve by manipulating some of the conditions related to binding. Based on the previous bachelor thesis (Braam, 2021; Drake, 2021, Dzhurkov, 2021; Koot, 2021; Wazny, 2021), we hypothesized that change detection accuracy will increase if the object being cued shared its identity with another object in the display, by the process of binding. According to the chosen model (CNM); if a presented object shares its identity with another object in the display, the memory trace involved will make multiple bindings, one to each location. As a result, two excitations pattern are providing excitation for the same cell assembly. Therefore, a memory trace for an object that appears twice will present a stronger memory representation because it is bound to two places in the spatial map. This will increase the feasibility of the cell assemblies action potential to exceed its critical threshold, implying the mitigation of change blindness.

Furthermore, we also expected the distance between objects sharing the same identity to improve change recognition performances if the objects are spatially right next to each other. Here, we hypothesized that adjacency between objects sharing the same identity will increase change detection accuracy. This is in accordance with the concept of scanning mechanism which states that external excitation enters in task serially which ensures that only one memory trace of an object and one location in the spatial map are activated one at a time. When the first binding has occurred, the next object will be processed by means of the scanning mechanism (See Figure 1). Thus, presenting objects that share their identity right next to each other will have a faciliatory effect on the memory trace because it becomes bound to two places which happens one after the other. This creates a higher activation level of the cell assembly which ultimately increases the speed of the activation level of the cell assembly to reach its critical threshold.

Regarding our central hypothesis, it was expected that change detection will be increased when the object being cued shared its identity with another object on the screen, and those objects were presented one after the other, as a means of, the automatic binding and the scanning mechanism.

The current experiment provides evidence for the conceptual network model and the serial binding mechanism. Our central hypothesis was supported; the shared identity and distance interaction effect improved detection performances. Our second hypothesis was also supported, sharing identity with another object in the display resulted in higher change detection. Finally, the third hypothesis was also supported, the distance between two shared identities other than the target will not significantly improve change detection. Regarding the participant's confidence score, we expected the results to follow the same pattern as the change accuracy performances. As expected, the confidence score follows the same pattern. Higher confidence scores when an object shared its identity with the object being cued. Even higher confidence scores when the object that shares its identity with the object being cued is placed directly next to it.

Besides the current experiment, four other experiments were part of the larger study. Again, all the experiments were divided between the two sets of state-change stimuli to control for possible object effects while varying in screen durations and cues. The current experiment presented a relatively short duration of the pre-change display and post cue mask but a longer duration of the pre-cue mask (See Table1), as compared with the other experiment using an indirect location cue, which used a longer pre-change display and post cue mask but a shorter duration of the pre-cue mask. These different screening durations appear to not affect detection performance which gives support to the conceptual network model and serial binding mechanism: the three hypotheses were supported (Griffiths,2022). Parallelly to the two similar experiments, three other experiments were conducted (Houter, Piletti & Van den Brink, 2022). The difference being the type of cue: identity and extended identity cue. This time, the multivariate test showed non-significant interaction effects for the two independent variables. The difference in findings between the experiment could be attributed to the type of cue. A plausible explanation on that matter would be that location cues already provide information about the location of change whereas identity cue just presents an image in the middle of the screen. Therefore, in the context of using a location cue the connection between spatial map and memory trace is strengthened, hence the chance of binding occurring is higher. Nevertheless, the main effect for shared identity was significant. Despite not confirming all the hypotheses, the experiment using identity cues provides support for the conceptual network model.

Therefore, in order to get further information about the role of binding conditioned by a cue in change detection, follow up study could investigate the detection performance by displaying more similar objects to force participants to pay attention to additional specific details.

Overall, the result of this experiment aligns with the faciliatory effect of identical objects and shared targets found by the previous bachelor studies (Braam, 2021; Drake, 2021; Dzhurkov, 2021; Koot, 2021; & Wazny, 2021). Specifically, the current experiment provides similar results as compared to the experiment of Dzhurkov (2021). The only difference is the use of exemplars instead of state-changes and the use of an identity cue. Therefore, additional support is given to the conceptual network model, and serial binding as an interaction effect between shared identity and location was found

In conclusion, the role of binding seems to play an important factor in change detection. The results provide evidence for the importance of binding related to visual perception and give insight into how binding can be manipulated based on the conceptual network model and the process of the serial scanning mechanism. The current experiment also demonstrates some similarities with eyewitness situations in the sense that in an eyewitness situation people were attending at a different spot than the accident, and then are asked to remember what was near that spot. This reassembles the case of an indirect cue in which a person gets oriented towards a specific location and has to think of an object left or right.

References

Braam, M. (2021). *The role of binding in a change blindness task conditioned by an identity cue*. Bachelor thesis, University of Groningen

Cooper, S. J. (2005). Donald O Hebb's Synapse and Learning Rule: A history and commentary. *Neuroscience and Biobehavioural Reviews*, *28*(8), 851-874. https://doi-org.proxy-ub.rug.nl/10.1016/j.neubiorev.2004.09.009

Dalenoort, G. J., & De Vries, P. H. (1998). *Downward processes in the perception representation mechanisms* (pp. 497–503). Singapore: World Scientific.

De Vries, P. H. (2004). Effects of binding in the identification of objects. *Psychological Research*, *69*(1-2), 41-66. https://doi-org.proxy-ub.rug.nl/10.1007/s00426-003-0159-0

Drake, K.B (2021*), Object identity and location's influence on binding in a change blindness task using a simple location cue*. Bachelor thesis, University of Groningen

Dzurkov, N. (2021*). The role of visual object binding conditioned by an extended location cue on the effect of change blindness.* Bachelor thesis, University of Groningen

Feldman, J. (2012). The neural binding problem(s). *Cognitive Neurodynamics*, 7(1), 1-11. https://doi.org/10.1007/s11571-012-9219-8

Griffiths, T.K. (2021). *Evaluating a conceptual network model through state changes in a computerized change blindness task*. Bachelor thesis, University of Groningen

Hebb, D. O. (1949). The organization of behavior. New York: Willey

Houter, J.V. (2021). *Change Blindness for states changes when using an extended identity cue*. Bachelor thesis, University of Groningen

IBM Corp. Released 2019. IBM SPSS Statistic for Windows, Version 26.0. Armonk, NY: IBM Corp

Konkle, T., Brady, T. F., Alvarez, G. A., & Oliva, A. (2012). KONKLAB. http://konklab.fas.harvard.edu/#

Koot, B.E.L (2021). *How binding conditioned by a retro-location cue affects detection in state changes. Bachelor thesis*, University of Groningen

Lacroix, G. L., & Giguère, G. (2006). *Formatting data files for repeated-measures analyses in Passing the aggregate and restructure procedures*. Tutorials in Quantitative Methods for Psychology, 2(1), 20-25. doi:http://dx.doi.org/10.20982/tqmp.02.1.p020.

Lamme, V. A. F. (2003). *Why visual attention and awareness are different. Trends in Cognitive Sciences* Luck, S. J., & Vogel, E. K. (2013). Visual working memory capacity: From psychophysicsand neurobiology to individual differences. *Trends in Cognitive Sciences, 17*(8), 391-400.

Prolific (2022). *https://www.prolific.co/*

Mathôt, S., & March, J. (in press). Conducting linguistic experiments online with OpenSesame and OSWeb. Language Learning

Piletti, V. (2021). *Investigation on the influence of the binding process in a change blindness task using an identity cue*. Bachelor thesis, University of Groningen

Simons, D. J., & Levin, D. T. (1997). Change blindness. *Trends in Cognitive Sciences*, 1(7), 261-267. https://doi.org/10.1016/s1364-6613(97)01080-2

Van den Brink, I (202). *The role of binding in the Change Detection of State-changes: A follow up study*. Bachelor thesis, University of Groningen

Wazny, O. J (2021). *Investigation of the influence of object identity and location on the role of binding in a change blindness task using an extended location cue.* Bachelor thesis, University of Groningen