Investigation on the influence of the binding process in a change blindness task using an identity cue condition

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Abstract

The phenomenon of change blindness is defined by the failure to perceive a change in our environment. In this follow-up study, this phenomenon is examined by reproducing such change on a digital screen and analyzing its effects under specific conditions of distance and identity, measuring participants' detection accuracy and confidence. The framework used for this experiment (N=34), is the conceptual network view (de Vries, 2014), which observes the neural dynamics behind binding and the phenomenon of change blindness, accounting and providing evidence specifically for the role played by the conditions of adjacency and identical identity, which were therefore manipulated, in the number of temporary neural connections between cell assemblies, their spatial map and its memory traces linked to the identity of the target object. Following the most recent and similar line of research by fellow students from the University of Groningen, it was hypothesized that 1) there would be an interaction effect for target identity and distance for the scoring accuracy measure, that 2) the adjacent/shared-identity condition would provide for significantly higher accuracy in comparison to the other three conditions and that 3) the confidence ratings would statistically follow the trends of the accuracy rating, The results showed no significant difference between the adjacent/non-adjacent condition, opposing the first hypothesis. Confirmatory results were found for the second and third hypotheses, respectively linked to the condition in which the highest accuracy was recorded (shared-identity/adjacency) and the parallel nature of confidence ratings and scoring accuracy.

Keywords: change blindness, binding, identity cue, change detection task

Introduction

When thinking about our perception we often find ourselves overestimating our capacity to successfully gather information about our environment and to recognize how details might change. For humans, visual perception is tightly linked to attention and memory and this makes it everything but infallible (Simons & Levin, 1997). While watching a video on the internet on how to bake a pumpkin pie, for example, you would probably not notice the cook's hair tie's sudden change of color at minute 14:09, as your focus would be directed toward the tutorial, which would function as a distractor. This specific phenomenon is called "change blindness" and it explains how an external stimulus could be subject to a given change without ever being noticed by the observer (Simons & Levin, 1997). The phenomenon of change blindness can be explained by and is tightly linked to the process of neural binding. In this thesis, the term "neural binding" refers to the process in which different and unique features of different objects in our visual field are neurally combined, such that their identities and locations are processed correctly and stored in our short-term memory. The phenomenon of change blindness derives from this specific dynamic, as mentally stored representations of objects before and post change are potentially compared and matched according to these features, consequently influencing the change's failed or successful recognition. This paper will be a follow-up study to previous research on change blindness seen through the process of binding, more specifically regarding the identity and location of a given changing stimulus (de Vries, 2004 & Braam, 2021).

The issue of change blindness, and consequently of the underlying principle of binding, can be analyzed under the lens of two main levels of descriptions. A functional, higher level of description deals with a holistic view of these processes, hence a top-down interpretation, that considers the outcomes and implications of binding rather than the building stones of its neural

mechanisms. Contrarily, in the structural level of description, or bottom-up modeling, binding takes into account and identifies the neurological and structural basic components of the brain involved in perception and how these interact with each other. The two levels of descriptions are highly complementary and it is impossible to fully understand concepts such as change blindness without drawing insight from both perspectives (O'Reilly & Munakata, 2000).

Analyzing these mechanisms on the structural level of description, when an object is observed by a perceiver, a temporary connection is created between its identity and its location, processing these features serially and storing them independently, in separate cognitive maps. These features are, consequently, connected by a non-permanent link (De Vries, 2004). If hypothetically, the mental processing of stimuli's identity and location were not independent of one another, then we would have to store a very large variety of object-location combinations in our memories, making the storing process of our minds far less flexible and adaptable to change than it already appears to be (Simons & Levin, 1997). A network of neurons that becomes activated due to a specific mental process is called a "cell assembly". The phenomenon of change blindness and the process of binding are directly related to the simultaneous activation of two different cell assemblies in the same context, supported by an already existing, context-dependent excitation in the subnetwork. This process can create a unique temporary connection between the two cell assemblies related to the location (spatial map) and identity of an object, specifically. Every cell assembly has a critical threshold, which is only surpassed once the excitation of the neural pathway is strong enough for the feature to reach awareness. Even when the excitation reaching the cell assembly is not strong enough to surpass the critical threshold, that specific neural connection will be strengthened regardless, making the activation through subsequent excitation more likely and widespread. Following a further exposure to the same

stimulus, a known neuronal pathway is re-activated, which leads to the consolidation of the cell assemblies and to the creation of memory traces that are then stored in short-term memory. The Conceptual Network Model explains the mechanism behind this phenomenon, starting from the creation of a temporary memory trace, its activation, and repeated excitation patterns (de Vries, 2004). These dynamics are related to the "Hebbian learning rule", which explains how neurons that wire together, fire together, leading to learning through the strengthening of the connection between cell assemblies. This highlights the importance of association and of familiarity won through repeated exposure and priming of the brain to the same stimuli or stimulus combinations. (Morris, 1999; de Vries, 2004).

Observing the neural mechanisms of binding under this lens, researchers have often come across a theoretical discussion around the "binding problem" (Zhang, Zhang, & Fang, 2020). The binding problem highlights the question of how the brain is able to perceive and represent objects' features and properties as one singular entity across different contexts and how the structural mechanisms can possibly translate into awareness and attention on a functional level (Zhang, Zhang, & Fang, 2020). The exact dynamics behind the timing and order of neural firing is still unknown, for this reason, the analysis of the precedence and amount of information that our brain can process within a specific environment, as well as the given novelty/familiarity of the stimulus' identity and location, still evokes questions (Pashler, 1988).

When it comes to the simultaneous presentation of multiple different objects, especially, a further difficulty is added to the process of tapping into the resource of memory traces through binding, as these become active serially and sequentially through the scanning mechanism, only one pair of location/identity stimuli at a time. In these cases, it is possible for the initial activation of the neurons in the cell assemblies, which are linked to the spatial map and the

object identity, to be so low as to prevent their autonomous excitation and hinder the reaching and surpassing of the critical threshold, resulting in the failure in reaching awareness. This way, as the binding between the cell assemblies of object identity and the corresponding spatial map, cannot happen simultaneously for multiple stimuli on a given frame, the process of scanning would require a given window of time (de Vries, 2004). Moreover, according to previous research, there seems to be a limited number of items that can be stored in the working memory at once. The slot-based model argues that there is only a limited number of "slots" that can be stored in the working memory at the time and, as working memory decays over time, a slot must be subjected to repeated firing in order to improve and maintain the accessibility of information related to items. For multiple slots to be active at the same time, these have to fire and be activated in a serial manner (Luck & Vogel, 2013). These theories are at the roots of some previous studies on binding and change blindness, which this follow-up research builds upon.

As illustrated by de Vries (2004), the workings of serial binding and scanning can be shown through an object identification task, built by operationalizing the neural conceptual network. The underlying principle and procedure of an object identification task related to change blindness are as follows: 1) the presentation of stimuli pre-change, 2) the masking, 3) the target cueing (location, identity, extended identity) occurring during the masking and 4) the presentation of the post-change stimuli. In de Vries' experiment, four letters were briefly presented on the display for the participant to see and quickly masked after. An arrow indicated successively a specific location (location cueing). The question was asked, as the mask was removed, whether a given letter occupied that position previously. De Vries's experiments were focused mainly on the recognition potential of a particular location and identity through the process of serial binding. Moreover, he questioned the role of the number of identical letters

within the frame, the different roles that those identical letters occupied within the experiment, and the influence of presentation time. According to de Vries' work, the familiarity and repeated occurrence of known stimuli (identical letters) and stimulus-location combinations increasingly speed up the excitation loops of the neuronal cell assemblies, reaching and surpassing the threshold of perception quicker, hence having a bigger probability of bringing information into awareness and short-term memory. This highlights the mitigating effect that shared identity and adjacency of objects have in the context of change blindness. This has been theorized to be due to the convergence of different temporary connections on the same memory trace (de Vries, 2004). By positioning identical items adjacent to one another, de Vries theorized that the object identity and the spatial map might become activated simultaneously due to the resonant context, which would increase the excitation of neural paths and result in binding in a shorter frame of time, despite the serial manner of the binding process and the scanning mechanism (Figure 1). Consequently, significant results from this research indeed confirmed that identical stimuli would elicit a quicker reaction time.

Figure 1.

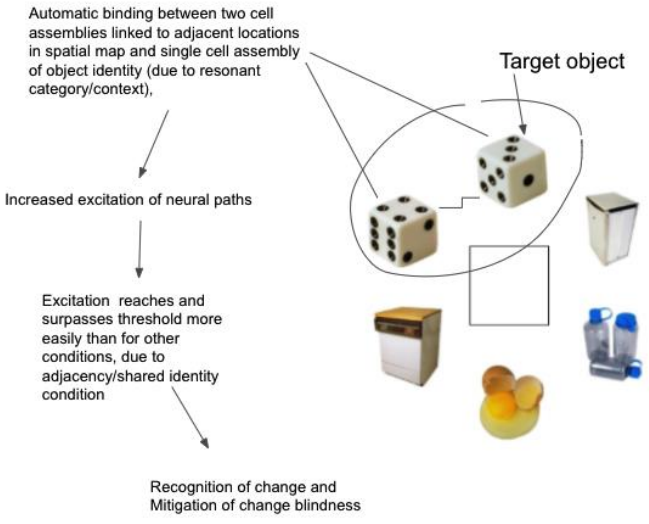

Fig. 1: The rationale behind the hypothesized effect of adjacency and identical identity in the binding process according to the neural conceptual network.

Some follow-up studies have already been conducted on this effect throughout the years, following de Vries' hypotheses. Latest attempts by a group of fellow students of the University of Groningen (Groningen, 2021) to investigate this dynamic, have utilized a set of pictures of different everyday items from a comprehensive database, each having a related paired picture entailing a state- or an exemplar change. State changes entail manipulation of the picture at hand, turning objects from whole to halved, empty to full, etc. In the exemplar changes, on the other hand, objects were substituted in the post-change display by relative items of the same category (e.g., two different dogs, both with bows on their heads). Six pictures were displayed circularly on the screen, randomly containing pairs of similar/identical items, for a given brief amount of time. The pictures were then masked and a location, identity, or extended identity was cued to test if the participant could recall the modified target object once it was made visible again.

In the study conducted by Braam (2021), which the current research builds upon, the utilized cueing method was the "identity cue", rather than the "location cue" used by the Vries in his previously quoted study. The identity cue method implies that the target object itself would be shown briefly during the masking process, between the pre-change and post-change display. The target object, hence the object that will be either to the right or to the left of the object subject to change, is appositely not shown before the pre-change display, as it is important for the participant to remember the display without knowing which object to focus their attention on, so as to really employ their working memory (de Vries, 2004, Braam, 2021). Braam's study specifically aimed to test the most desirable combination of an object's identity and positioning within the presented group, which was hypothesized to be 1) identical object identity and 2) its adjacent positioning. The goal of the study was to test if this combination would elicit a more accurate response by the participants, hence inhibiting the occurrence of change blindness and

confirming the effect supported by the neural conceptual network. The hypothesis in Braam's study concerning the identification facilitation due presence of identical objects was confirmed. Contrarily, the second hypothesis of the positioning of the identical objects was not confirmed, as mere adjacency did not lead to an increase in accuracy in the change blindness task without the effect of shared identity.

Among the experiments conducted by this research group, all the studies found evidence for the effect of heightened sensitivity related to objects with shared identities within the matrix versus objects with unique identities (Hypothesis 1). Only two experiments found evidence for the role of the adjacency of the identical object plays a significant role in the higher degree of sensitivity related to an item (Hypothesis 2) (de Vries, Braam, Dzhurkov, Koot, Drake, Wazny, 2021). More evidence for the effect was found among studies entailing exemplar changes than state changes. For the extended cue experiment conducted by Wazny (2021) as part of the same research group, with a sample entailing exemplar changes, additional evidence was found for the role played by the adjacency of identical objects and for their interaction effect.

The current study will be replicating the object identification task described in the previous paragraph, utilizing the same image database used by the previously cited student researchers of the University of Groningen (de Vries, Braam, Dzhurkov, Koot, Drake, Wazny, 2021). The current experiment will build upon Braam's study specifically, as it will take on the same methodological characteristics, like the identity cueing and the state change variable. In this study it is hypothesized that 1) an interaction effect would be found for distance and identity 2) that the adjacent/shared-identity condition would provide for significantly higher accuracy in comparison to the non-adjacent/non-shared identity condition. Moreover, 3) it is hypothesized that the confidence ratings will statistically follow the trends of the accuracy rating, as to confirm

a degree of consciousness related to the mitigation of change blindness by adjacency and shared identity.

This study will be part, more generally, of a broader research in tandem with four other fellow students from the Bachelor's program at the University of Groningen, who will be testing other variables relating to the same topic with identity, extended identity, and location cueing. Experiments one (Griffiths, 2022) and two (Garcia Martin, 2022) utilized a location cueing (the cue is only briefly indicated by a red line), experiments three (Piletti, 2022) and four (Van den Brink, 2022) utilized identity cueing and experiment five (Houter, 2022) and six (De Vries, 2022) utilized extended identity cueing. In both the identity cues and extended identity cues the object being cued is displayed on the screen, yet in the extended identity cue, the object cued stays visible during the post-change screen. For the studies within this research group, the choice was made to utilize images linked to state changes instead of exemplar changes. This was a direct consequence of the smaller amount of evidence found for the hypothesized effect for this specific variation in the previously mentioned studies. Moreover, the task has been simplified by removing the option "no change" from the previously used three response options: "no change", "change has occurred on the right of the cued object" and "change has occurred on the left of the cued object". This option was removed to decrease the difficulty of the task, which was deemed overly challenging. To avoid effects linked to specific images or objects used, two different sets of images were utilized. These studies will be reported on and their results will be compared systematically in the discussion of this paper. The aspects of the experiment that are being manipulated are, among others, the timing of the different pre-and post-change displays and the masking display. Furthermore, the current research group included an additional variable to measure the participants' confidence in the accuracy of their answers related to the selection of

the post-change image. This variable will presumably be useful to measure the subconscious versus conscious identification of the target image and state change and would account for more balancing and control when it comes to the phenomenon of guessing. Moreover, it is meant to measure the degree of perceived task difficulty. Building upon the studies discussed previously, the current research will investigate whether an interaction effect is present between distance and identity and in what capacity, whether the adjacent/shared-identity condition will again provide for significantly higher accuracy in comparison to the non-adjacent/non-shared identity condition and whether the newly introduced confidence ratings match the trends of the accuracy rating.

Methods

Participants

The participants for the experiment were recruited from a participant pool consisting of the first-year students in the Psychology department at the University of Groningen (Groningen, 2022). Some of the participants were also asked to participate by the researchers directly, as it was allowed to ask colleagues, friends, and family members (excluding minors) to take part in the study. The total number of participants in the study was 37, yet during the analysis three had to be discarded from the final dataset due to suspicion of misinterpretation of the procedure or guessing by random clicking. This was observed through the very low scoring of these participants, which fell significantly below the guessing rate for every condition, which was 50% if the instructions of the study were correctly understood and the cue was correctly remembered and 16.66% if they did not. The final dataset consisted of 34 participants, of which 10 were male and 24 females (29.45% and 70.05% respectively). The average age of the participants was 20.75, ranging from 18 to 48 (χ= 23.9 for males and χ=19.41 for females). The duration of completion was χ=242.7 seconds for males and χ=279.04 seconds for females, making the

females slightly faster. The outline of the study was sent to and approved by the Ethics Committee BSS (Groningen, 2022).

Design

The design consisted of the interaction of two independent variables: 1. the shared identity between the object and the target object and 2. the distance of identity sharing objects and the target. The target would be either adjacent to the identity-sharing object or other unrelated items would be present between the target and the identity-sharing item. These two factors resulted in four conditions: 1) the target object is positioned adjacent to an item, with which it also shares identity. 2) the target object shares identity with another item on the display, yet they are not adjacent. 3) Two identical, adjacent objects are present on the display, yet none of them function as targets in the trials. 4) On the display there are two items sharing identity, yet they do not function as targets in the trial and they are separated by an unrelated item. The dependent variables of this study are the participants' guessing accuracy and their confidence level. In Figure 2 the different conditions of the experiment are displayed.

Figure 2.

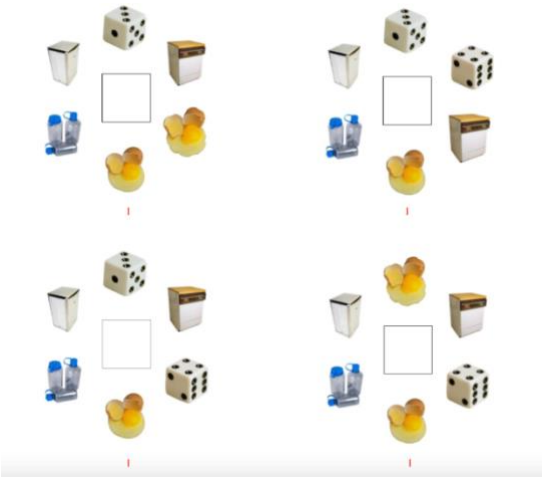

Fig.2: In this case, the target object is the egg (marked by the red line). In the top right: identical objects do not share identity with the target object but are adjacent, bottom right: identical objects share the identity with the target object but are not adjacent, top left: identical objects share identity with the target object and they are adjacent, bottom left: identical objects do not share the identity with the target object and are not adjacent.

Material

The material for this study was a series of 200 object images (de Vries, 2004 & de Vries, Braam, Dzhurkov, Koot, Drake, Wazny, 2021). The images were divided into pairs of almost identical images with subtle state changes. The same pairs of images were used for both the practice trial and the actual experimental procedure so that the same images and respective state changes could occur multiple times throughout the study. This would allow the participants to familiarize themselves with the images. The selection of the images resulted in 6 categories with respectively 4 pairs of images belonging to this experiment, namely: storage, household appliances, electronics, entertainment, and drinks. Every item presented in a display was to be from a different category, so as not to confuse the participant and to maintain a level of distinctiveness between objects. This was vital to avoid confounding variables related to object similarity and association. Two pairs of objects from the same category in one display would have probably affected the results and created confounding variables in the experiment, as grouping similar objects or entities together would result in a different and more categorical activation of the working memory. The object images selection procedure aimed to make the state changes subtle and the recognition of change rather challenging than blatant. The reason for this choice was to assure that the detection of change was entirely based on the activation of a memory trace rather than visual memory. An example of the images used in the experiment is "the red box". Presented is also its state change in the experiment (Figure 3).

Figure 3.

Fig. 3: The object image called "the red box" and its respective state change.

Procedure

The participants were provided an informed consent form before the experiment's beginning, in which the study's instructions were thoroughly described and the voluntary nature of their participation was pointed out. They were also reminded that they could retract their data from the study at any stage. The experiment was to be completed individually, preferably in a quiet room and with as much of the possibility to focus on the task as possible. The experiment was performed within OSWeb (Mathôt, Schreij & Theeuwes, 2012). The participants were firstly presented with information on the study, which they had to read carefully. This procedure was completed through a questionnaire on Qualtrics (Provo, Utah, USA). This section entailed practical and ethical information on the study. Its function was to serve as an introduction that could help the participants understand the instructions of the experiment and give their informed consent to the active usage of part of the data collected through the experiment to the University of Groningen. The data collected was anonymous and included as part of the cases' analysis from this platform were the participants' gender, age, the date and time of completion, and their score on the trial as well as on the experimental block.

Following the Qualtrics (Provo, Utah, USA) questionnaire, the participants were redirected to the OSWeb platform (Mathôt, Schreij & Theeuwes, 2012) and were asked to complete 2 practice blocks with 8 trials each, for which they were given feedback, and 4 experimental blocks with 24 trials each, for which they were not given any feedback. The practice blocks and the experimental blocks followed the same standard procedure, entailing 3 main displays and one mask: firstly, the participants were presented with a blue square that they were required to click on with the mouse once they felt ready to start a trial. Thereafter, Screen 1 would be presented (Figure 4a.). Screen 1 would show a selection of 6 circularly displayed

object images. The object images would appear on the screen for a brief amount of time and then be covered by a mask (gray squares hiding the previously shown object images) (Figure 4a). The mask's function was to conceal the objects images before the change, reset the participants' visual field, and avoid the effect of movement that could occur with the insertion of a state change. The recognition of change was meant to occur through the activation of memory traces instead of visual change detection. During the mask, an identity cue was presented. The identity cue was displayed in the middle of the circle created by the masked object images. The identity cue would show one of the object images presented in Screen 1, more specifically the one that would be adjacent to the two object images that could undergo a change in the upcoming third Screen (either to the cue's left or to the cue's right side). The identity cue's function was to trigger a memory trace related to the target object and adjacent objects in the pre-change display and to reactivate it. Following the mask display, the third and final screen was presented. Screen 3 reproposed all of the items of Screen 1, with the only difference being the presence of state change in either one of the images adjacent to the item displayed previously during the mask as an identity cue. This dynamic is displayed in Figure 4a., in which the object of "the red box" is presented as the cued object during the mask. The target object, which is adjacent to the cue and is undergoing a state change, is the "coffee cup", which, in this case, is located to the left of the previously cued object ("the red box"). The state change linked to "the coffee cup" is displayed by the cup being full in the pre-change display and empty in the post-change display. The participants aimed to identify the state change and click on the item that underwent it, according to their perception and memory. Throughout the experiment a state change per trial would occur as, opposite to related previous studies, the option of "no change" was not present. Once the selection of the item was made by the participant, it was not possible to modify the choice.

Following their guess, the participants were asked to rate their confidence in the selected item on a scale from 1 to 5.

Concerning the practice trials, the feedback was given after each trial, as to signal if the participant had successfully identified the state change. This was done using a visual cue, namely a colored square. The square can be seen in Figure 4a., in the center of every screen. The square would turn green in case of a correct answer and red in case of an incorrect answer. During the experimental trial, no feedback was offered, except for at the end of each trial, at which point the mean guessing rate of the participant was displayed. The practice trials were used mainly to let the participants become familiar with the task at hand, to ensure better final results, and to avoid a lack of understanding of the procedure's dynamic. After the experiment completion, the participants would be presented with their personal data and with an explanation. The study's research question and the individual responding accuracy were illustrated with the help of a bar graph for a better understanding of the results. The outcome distinction dependent on the adjacency and identical identity of the object was made visible. The following images illustrate the four screens in the experiment and their relative durations.

Figure 4a.

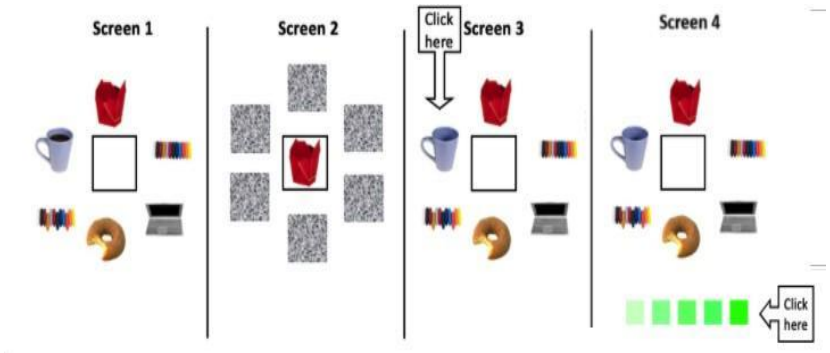

Fig. 4a: the trials' four screens

Figure 4b.

1000	Pre-change display
400	Pre-cue mask
250	Cue
750	Post cue mask

Fig. 4b: the duration of each screen

Results

This study entailed two main hypotheses, the first one concerning the independent variables of distance and shared identity as per previously conducted studies on the topic (Braam, 2021) and the second hypothesis touched upon the newly added variable of the confidence measure. With this experiment, the aim was to confirm the findings that adjacency and shared identity would make for significantly higher accuracy ratings in the participants' responses to state changes. Furthermore, it was of interest to investigate the role played by confidence level, hypothesizing that the confidence ratings would be significantly higher for trials in which the target was adjacent to an item with a shared identity and lower for non-adjacent/single identity targets. Consequently, the expectancy related to the results of the analysis was that an interaction between identity and distance would be present. Furthermore, congruence between the accuracy of responses and confidence levels was expected. It was hypothesized for the confidence ratings to follow the trends of the accuracy ratings; hence, they were estimated to be higher for trials with target objects in the condition of adjacency and shared identity than for the other conditions. The analysis was conducted utilizing two one-way ANOVAs and one 2x2 Repeated Measures ANOVA with the aim to investigate the interaction between the effects of shared identity and distance. The same procedure was applied both for the

correct means and for the confidence levels. Table 1 shows the statistical descriptive results for both accuracy ratings and confidence ratings and Figure 5 their graphical representation.

Table 1.

Descriptive statistics for the accuracy measure (accuracy means) and confidence measure (confidence means) between shared identity and distance, entailing the corresponding means (Mean), standard deviations (SD), and the number of participants (N).

Variables	Accuracy measure			Confidence measure		
	Mean	SD	N	Mean	SD	N
Non-shared identity/adjacency	.4551	.15877	34	2.6306	.63195	34
Non-shared identity/non-adjacency	.4372	.17796	34	2.6086	.64199	34
Shared identity/adjacency	.7086	.17485	34	3.9659	.54924	34
Shared identity/non-adjacency	.6366	.13998	34	3.6239	.50594	34

Figure 5.

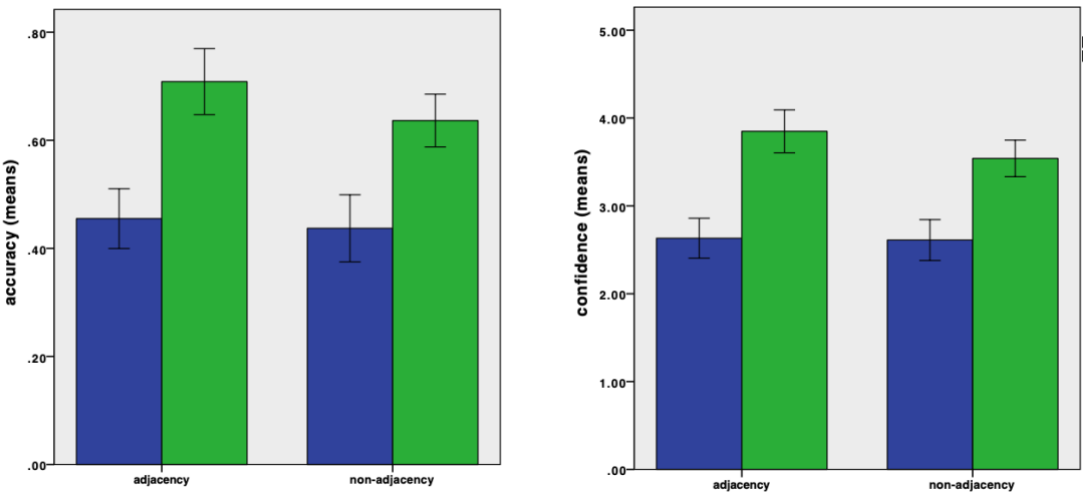

Fig. 5: the bar graphs correspond to the values of the descriptive statistics in Table 1, linked to the mean accuracy ratings (on the left) and the mean confidence ratings (on the right). A confidence interval of 95% is included. The blue bars represent the condition in which identity to the target object is not shared, while the green bars represent the condition of shared identity. The two bars on the left respectively are related to adjacency, while the two bars on the right to non-adjacency.

Correct Means

For the first part of the statistical analysis, the focus was placed on scoring accuracy between the means of the four different conditions of object distance and shared identity of target objects. This interaction was investigated by conducting a two-way 2x2 (shared/non-shared identity and adjacent/non-adjacent identity objects), repeated measure ANOVA. According to the results retrieved from the multivariate test, no interaction effect between identity and distance in rating accuracy was found ($F(1, 33) = 1.970$, $p = 0.056$; partial $\eta 2 = 1.970$), as the p value was not lower than 0.05, a result which contradicts our first hypothesis. Two more one-way ANOVAs were conducted for the individual variables, in order to investigate the absence of interaction further.

The computation of the first one-way ANOVA aimed to investigate whether a significant difference in sensitivity between the adjacent and nonadjacent conditions was present, also providing more insight into the interaction effect. For this computation the factor of shared identity was controlled for, so as to solely analyze the variables concerning the distance from the target object for this condition. The factor distance was used as an independent variable, while scoring accuracy was the dependent variable. The conditions of adjacency and non-adjacency from the target objects were statistically compared and the difference between them was shown not significant for the non-shared identity condition, as interpreted by the results retrieved from the multivariate test ($F(1, 33) = 0.426$, $\eta 2 = 0.518$; partial $\eta 2 = 0.00$). Likewise, the same results were confirmed by the pairwise comparison output, showing that the difference between the adjacency ($\chi = 0.455$, $SE = 0.027$, CI [0.40, 0.051]) and non-adjacency ($\chi = 0.437$, $SE = 0.031$, CI [0.37, 0.49]) to the target object was not significant, as the 95% confidence interval included the value of zero for both the condition of adjacency ($\chi diff = 0.018$, $SE = 0.027$, CI [-0.38, 0.074])

and non-adjacency (χdiff = -0.018, SE = 0.027, CI [-0.074, 0.038]). These results were indicative of the fact that the difference between the distance of one item to the target object and adjacency to it as a single factor seems not to be correlated to response accuracy in the not-shared identity condition. Nonetheless, participants' scores were more accurate for the adjacency condition, even if not significantly.

The same procedure was repeated by focusing on the shared identity condition. The goal behind the computation of this second one-way ANOVA was to single out the variable of shared identity in the previously observed interaction and to investigate whether the two levels of this condition, namely the adjacency and the non-adjacency, would show a statistically significant difference in the response accuracy of the participants in presence of the condition of shared identity. As determined by the multivariate test, a significant difference in location response accuracy between the levels of distance for the shared identity condition, namely adjacency ((χ= 0.709, SE = 0.030, CI [0.648, 0.770]) and non-adjacency (χ = 0.637, SE = 0.024, CI [0.588, 0.685]) was found ($F(1, 33) = 7.505$, $p = 0.010$; partial $\eta 2 = 0.185$), as the 95% confidence interval did not include the value of zero both for the condition of adjacency (χdiff = 0.072, SE = 0.026, CI [0.019, 0.126]) and non-adjacency (χdiff = -0.072, SE = 0.026, CI [-0.126, -0.019]). These results show that, for the condition of shared identity, a significant difference in the adjacency condition and the non-adjacency condition was found, indicating that distance does play a role in the accuracy of participants' responses and that the accuracy for the condition in which the target object and other adjacent items are identical is significantly higher. Participants' accuracy in scoring was significantly higher for the adjacent condition.

Confidence ratings

The same statistical procedure was applied replacing the factor of scoring accuracy with the one of the confidence ratings. The aim of this part of the analysis was to observe whether the scoring accuracy ratings would statistically match the confidence ratings of the participants on the four different conditions of object distance and shared identity, in order to indirectly gather more information on the role of consciousness in the recognition of change. This interaction was investigated by conducting another two-way 2x2 (shared/non-shared identity and adjacent/non-adjacent identity objects), repeated measure ANOVA, and subsequently using two further one-way ANOVAs to investigate this interaction in depth. According to the statistical results retrieved from the multivariate test, the interaction between shared identity and distance was significant, confirming our hypothesis ($F(1, 33) = 11.905$, $p = 0.002$; partial $\eta 2 = 0.265$).

As to further investigate this interaction, the first one-way ANOVA was conducted. This was done in order to explore the difference in confidence ratings in the distance condition, namely adjacency and non-adjacency, controlling for the identity factor, which was again used as a dependent variable. The factors of adjacency and not-adjacency were statistically compared under the prerogative of the condition of not-shared identity, first. The multivariate test indicated the difference between the conditions of adjacency and non-adjacency to be overall significant ($F(1, 33) = 20.297$, $p = 0.000$; partial $\eta 2 = 20.297$). According to the results retrieved from the pairwise comparison, confidence ratings for the not-shared identity/adjacency condition ($\chi = 3.966$, SE = 0.094, CI [3.774, 4.158]) and the not-shared identity/non-adjacency condition ($\chi = 3.624$, SE = 0.087, CI [3.447, 3.800]), were significantly different from each other. The 95% confidence interval included the value of zero, indicating that the difference between the two conditions was different than 0 (adjacency = (χdiff = 0.342, SE = 0.076, CI [0.188, 0.496], non-

adjacency = (χdiff = -0.342, SE = 0.076, CI [-0.496, 0.188]). These results indicate that a significant difference was found in confidence ratings for the two distance conditions related to the not shared identity factor, with the participants' scoring significantly more accurately in the adjacency condition than in the non-adjacency condition.

The second one-way ANOVA was conducted in an identical fashion, this time utilizing the factor of shared identity in order to observe the hypothesized difference in the confidence ratings linked to the distance conditions (adjacency and non-adjacency) from the target object. As determined by the multivariate test ($F(1, 33) = 20.297$, $p = 0.000$; partial $\eta 2 = 20.297$), an overall significant difference in confidence rating between the two distance conditions adjacency/non-adjacency was found for this analysis. These results indicate, consequently, that confidence ratings varied significantly according to distance in the shared identity condition. Also, according to the pairwise comparison, this result was confirmed, as the values relating to adjacency (χ= 3.966, SE = 0.094, CI [3.774, 4.158]), and non-adjacency (χdiff = -0.342, SE = 0.076, CI [-0.496, 0.188]), showed significant differences, the condition of adjacency being the one leading to the significantly highest mean score. This is indicated by the 95% confidence interval not including the value of zero for both the adjacency condition (χdiff = 0.342, SE = 0.076, CI [0.188, 0.496]) and the non-adjacency condition (χdiff = -0.342, SE = 0.076, CI [-0.496, -0.188]), making the difference between the two conditions significant. This supports the hypothesis that the location of the identical object being adjacent to the target object leads to higher confidence ratings than the location of the identical object being separated on the display by another unrelated object from the target object.

The results from the ANOVAs conducted for the correct means variable and the ones conducted for the confidence ratings variable do not align in significance, as in the confidence

ratings variable both the non-shared identity and shared-identity conditions have shown significant differences linked to the variable of adjacency and non-adjacency, while the correct means analysis did not match this result for the non-shared identity variable. Nonetheless, the scoring patterns suggest that there might be a link between scoring accuracy and reported scoring confidence per trial, as the condition of shared identity/adjacency accounted for the highest accuracy ratings in both variables. Likewise, the condition of non-shared identity/non-adjacency was the lowest scoring condition for both scoring accuracy and confidence ratings.

Discussion

In this study the influence of distance and identity in the detection accuracy and related confidence linked to state changes of target objects was investigated. It was hypothesized that 1) there would be a significant interaction effect between target identity and distance 2) that the condition of shared identity and adjacency would provide for the most accurate ratings and that 3) the accuracy-related confidence ratings would reflect the scoring accuracy of the participants. After analyzing the data, significant evidence was found for the second and third hypothesis.

The second hypothesis' confirmatory results indicated possible mitigation of the phenomenon of change blindness in the specific context of shared identity and adjacency. On a structural level of description, which this study has been focusing on, the identical identity and adjacency of the object would, as aforementioned, strengthen the temporary connection between cell assemblies linked to the spatial maps and object identity, and after repeated concentrated exposure of participants' perception to the target, due to the closeness and the similitude of the image in the immediate visual field, it would lead to a fast increase in neural excitation within the cell assemblies, which would surpass of the threshold. It would subsequently result in faster scanning and serial binding and lead to more efficient detection of change (de Vries, 2004). On a

functional level, the target object under the adjacency/shared identity condition can more easily reach awareness and be stored into short-term memory faster. This result confirms findings gathered from prior research on the topic, including the findings of the fellow-students of the University of Groningen that are part of the tandem group of this research (Griffiths, Houter, Garcia Martin, Van den Brink, 2022). It also aligns theoretically with the neural conceptual network theory (de Vries, 2004).

Providing evidence for the third hypothesis and as depicted in the graphs and descriptive statistics in Table 1 and Figure 5, the confidence ratings followed the trend of the accuracy ratings. This result hints at the possibility of a higher degree of awareness linked to the level of ease experienced during the change detection task in the adjacent/shared identity condition compared to the non-adjacent/non-shared identity condition from the participants' perspective. Not only was the task of change detection easier for the participants during the trials belonging to the adjacent/shared identity condition, but this effect also evidently reflected in the individual evaluation of their own performance just after the selection of the object. Comparing the current results to the results from other experiments belonging to the research tandem, it became evident that all the experiments found an interaction between the confidence measure and the accuracy measure. The confidence ratings matching the accuracy ratings statistically hint at a positive correlation between response accuracy and confidence.

On the other hand, no significant evidence was found for the first hypothesis, which claimed that there would be an overall significant interaction effect of distance and target identity when analyzing scoring accuracy. This might be due to the main effect of distance in the shared identity condition not being large enough. This might also indicate that, within the interplay between adjacency and identity and while aiming at the mitigation of the phenomenon of change

blindness, the shared identity to the target object is the key factor and a requirement for heightened accuracy or a difference in accuracy overall. This aligns with the findings of Braam (2021), who, analyzing the same condition, found very similar results. Likewise, similar results were found in the experiment of Van den Brink (2022) and the experiment of Houter (2022) of the current research group. The experiment of Griffiths (2022) and the one conducted by Garcia Martin (2022), on the other hand, showed significant interaction effects of distance and target identity related to the variable of scoring accuracy. The main effect of shared identity and adjacency was found in every study (De Vries, Griffiths, Garcia Martin, van den Brink, Houter, 2022).

Certain limitations of this study could be addressed in future research. One such limitation would be the relatively small size of the dataset used and its relative unrepresentativeness, probably due to the sampling method. One further limitation could have arisen from other confounding variables related to the target objects, which this study could have failed to take into account and properly control for. An example of such confounding variables would be an unknown aspect of the target object's identity that would make the image particularly salient and vivid to participants. Despite these limitations, the previously presented results suggest practical implications for the study of the phenomenon of change blindness, as a further facet, the confidence variable, was added to its field of interest. In terms of future research on the topic of change blindness, consequently, it would be interesting to focus on the aspect of awareness and on getting a deeper insight into the participants' perceptions. Furthermore, according to the comparisons to the other experiments within this research group, it could be insightful to further investigate the effects of different types of cueing. Interestingly, the experiment conducted by Griffiths (2022) and the one conducted by Garcia Martin (2022)

employed location cues instead of identity/extended identity cues and were the only studies of the research tandem that found significant interactions between target identity and distance. This specific effect could have arisen from the simplicity and directness of the location cue, which does not involve imagery but merely guides the participant's attention to the location of the cued object. With other types of cues, especially the simple identity cue, in which the cued object is only presented for a brief moment during the mask, the participant has to take on the cognitive load of memorizing the cued image and, subsequently, finding its location. This dynamic could potentially negatively influence the performance and scoring accuracy of the participants, as they would not know where to direct their attention to accurately detect the change. For further research, different types of cueing could be presented: a practical example would be the use of a colorful circle to highlight the location of the object during the mask, to then remove the cue in the post-change display. Different types of cueing could also be employed in the same trial, as to detect the statistical difference between the participants' scoring accuracy depending on the types of cues. In summary, this research replicates the study of Bram (2021), following the study of de Vries (2004) on the role of binding in change blindness research, based on the neural conceptual network model. The findings in the current study contribute to a growing body of evidence that will help understand the occurrence of this phenomenon and the cognitive mechanisms behind it, as well as awareness and memory.

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