"Judging a Book By its Cover?": The Impact of Superficial Contextual Information on Digital Flashcard Learning

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Abstract

Research from visual search suggests that contingencies between contextual information and responses can be learned. The ability to form these associations may also be applicable to digital flashcard learning to provide additional cues. The present study aims to investigate how superficial contextual information impacts study performance and cue processing in a digital flashcard setting. The hypotheses are that lowering the predictability of contextual cues by varying the spatial layout or the syntax of the cue a) improves cue content processing as seen in test performance and b) slows reaction times during the study session. A two-block mixed design was used with the first block for measuring individual baseline performance and the second block for introducing cue manipulations. In each block, 46 participants (all aged 17-25) studied concepts for 15 minutes in a digital flashcard setting, followed by a two-minute Tetris task and a test. Results suggest that varying the predictability of contextual cues does not affect reaction times or test performance. However, response accuracy during study sessions was found to be negatively affected by spatial layout variations. Thus, there is some evidence that contextual cues affect the study process, though differently and less extensively than in visual search. The findings are also in line with research on sentence memory and syntax as well as research on encoding specificity. Future studies into the matter are warranted to guide the development of digital flashcard algorithms.

Keywords: contextual cueing, associative learning, adaptive learning systems

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Every piece of information occurs within a context, whether it is the time of day, the visual surroundings or other contexts. The context can be random and not directly associated with the information. However, in most cases, the context may provide information about the presence of other information on a regular and predictable basis. According to Gibson (1966), our brain acknowledges such invariant contingencies and uses them to improve future perceptual functioning. In essence, the brain learns to benefit from contextual contingencies to predict the occurrence of a stimulus. This type of learning is of particular importance as it allows us to quickly extract predictive aspects from the overwhelming amount of information available in our environment to expedite cognitive processing. While contextual cues have been studied extensively in visual search, learning and memory research have not focused much on the predictive contingencies found in the superficial appearances of cues. In flashcard learning, contextual information can be operationalized as the physical appearance of the cue and its elements.

The potential effects of these contingencies are of importance to *adaptive learning systems,* which are designed to optimize the learning process and consider the individual differences between learners to adjust themselves based on the learner's performance. Whereas one-to-one learning of vocabulary does not provide much variability in contextual information, learning the definitions of concepts can introduce substantial variations in the superficial contextual information due to their increased variability in length. As adaptive learning systems often rely on reaction time to assess the current accessibility of a memory trace, any factor impacting reaction times, such as the predictability of contextual information, could affect the efficacy of these systems.

Literature Review

Memory Models

The ACT-R framework is a cognitive model that aims to describe and formalize memory processes and is commonly used by adaptive learning systems (Pavlik & Anderson, 2008; van Rijn et al., 2009). The model states that each piece of information receives an activation level upon encoding that decays with time (Anderson et al., 2007). Each retrieval of the information increases the amount of activation inversely proportional to its activation level at recall and changes the decay rate so that a lower level at recall leads to lower decay. Thus, larger intervals between testing sessions lead to more durable memory traces, reflecting research on the spacing effect (for a review, see Cepeda et al., 2006). Reaction times in ACT-R are supposed to reflect the cognitive processes of retrieval and the activation level of a memory trace, allowing the mathematical modelling of memory and forgetting. Notably, while the model does account for Anderson's *fan effect*, which relates to the increase in retrieval time the more information is associated with a concept (Anderson & Reder, 1999), it is unclear how visual contextual information falls under the fan effect as studies have primarily focused on semantic information. The impact of visual contextual information is particularly important because it does not add semantic information but learned context-specific associations that do not reflect the depth of understanding of known information. Therefore, research into the effects of eliminating contextual cues on performance in adaptive learning systems that use ACT-R is warranted.

Contextual Cueing

As previously mentioned, the physical appearance of the cue and its elements can be considered contextual information within a cue. In heterogeneous learning sets, the physical appearance can provide predictive cues for the required response and potentially narrow down the possible response space. For example, the cue "Whether a detector or node has been activated in the recent past" has specific physical characteristics immediately apparent upon seeing it, such as using one line or having a long word in the centre. Users may implicity learn the association between this contextual information and the correct response "recency" and use this information as an additional retrieval cue in addition to the provided semantic information. Thus, the availability of predictive, contextual information provides a cue within the to-be-learned cue.

The most well-known case in which slight differences in visual contextual information can help performance is contextual cueing. Chun and Jiang (1998) found that participants in their study could learn the spatial layout of repeated visual search arrays to identify targets more quickly. They termed the effect *contextual cueing* as participants used contextual information to enhance performance. Thus, contextual cueing refers to the implicit learning of associations between contextual information and target locations. In particular, the spatial relationships near the target are of primary importance. These effects are distinct from repetition priming effects as a later study by Chun and Jiang (2003) showed that they can occur even if the first presentation of a search array occurred multiple trials prior and can even show up after delays of up to one week. Importantly, these studies also found that contextual cueing is an implicit process, as participants could not recognize search arrays at a better level than chance. Whereas contextual cueing is traditionally thought of as a form of attentional guidance via the systematic biasing of priority maps, such as how Awh and colleagues (2012) propose, there is also a line of reasoning that suggests that contextual cueing may result from response facilitation upon identification of a target (Kunar et al., 2007). How contextual information affects cognitive processing in learning tasks involving reading is unclear though contextual cueing provides evidence that the associative learning between slight differences in visual contextual information and their respective responses does occur in visual search tasks and may occur in flashcard learning.

Good-Enough Processing and Encoding Specificity

Importantly, the cues provided by the contextual information may promote sufficient but less efficient learning during a study session as task demands in flashcard studying are relatively low. According to the *good-enough processing* account by Ferreira and colleagues (2002), task demands determine the depth of processing. This account was later extended into the *Online Cognitive Equilibrium* account, which posits that readers try to reduce uncertainty when reading information by engaging in both systematic and thorough (i.e. deep) processing and heuristic (i.e. shallow) processing at the same time (Karimi & Ferreira, 2016). Once uncertainty is reduced, the sentence comprehension system attempts to maintain the reinstated equilibrium and avoids further processing. Heuristic processing creates the initial interpretation as it is faster by nature, which explains why garden-path sentences, which require thorough processing, mislead readers. In addition, because the system attempts to maintain equilibrium, the effect that memory of garden-path sentences or similarly complex sentences usually reflects the faulty interpretation (Christianson et al., 2001; Ferreira et al., 2001; Patson et al., 2009) can be explained. In flashcard learning, the task demands are comparatively low as learners only need to distinguish between the contents of the amount of items included in a set. Because learners are only required to provide a correct answer for a small collection of definitions (usually, the item list is limited), the predictive information provided by the context can be an influential component of the retrieval process.

Furthermore, it is essential to note that retrieval success is considered a function of the match between the cognitive processes employed during encoding and retrieval (Tulving & Thompson, 1973; Roediger & Guynn, 1996). Suppose contextual information plays a considerable role in the encoding and retrieval process during studying with adaptive learning systems. In that case, the lack of availability of these cues during later testing might negatively affect retrieval success. In contrast, if contextual cues are unreliable predictors, more effort would be spent using the semantic content as a cue, as the fast processing of contextual information is less fruitful. Learners would then achieve greater independence from contextual information which is unlikely to be constant outside of the adaptive learning environment.

The Present Study

The effects of contextual cues on the learning process are unclear and could impact the performance of adaptive learning systems. Research from visual search suggests that people can learn predictive associations between contextual information, such as the spatial layout, and required responses to improve task performance. Thus, the present study investigates the effects of reducing the individual predictability of contextual cues on memory using digital flashcards by introducing added variance in the spatial layout of the cue and the locations of specific words via syntactic transformations. It is predicted that retrieval times will increase due to the increased amount of associated information, as Anderson's fan effect suggests. In addition, participants will show a deeper understanding of the learned concepts, as decreasing the predictability of irrelevant contextual information should increase the relative predictability and attractiveness of encoding largely based on semantic information.

Varying the Spatial Layout

Alternating the spatial layout of a cue would result in a change in the spatial relationships between the words. As contextual cueing is based on these relationships between elements in a display, alternating them should hinder the usability of contextual cues. By reducing the predictive value of the spatial layout, these additional cues cannot be readily learned and are thus less likely to influence the retrieval process. In addition, research has shown that the learning process in contextual cueing is an all-or-nothing process rather than a gradual learning curve (Spaak & de Lange, 2019). Thus, more exposure would be required to establish contextual cueing.

Due to the unavailability of predictive contextual cues, learners must process the information more thoroughly, as the context cannot guide them to disambiguating features. This manipulation should, in theory, lead to improved future recall of cue-related information and strengthen the connection between cue and response.

Varying the Syntax: Syntactic Awareness and Retrieval Effort

Another way to change the global layout but also the local structure of the cue is to transform it syntactically. This change would reduce the availability of contextual cues and require learners to exercise *syntactic awareness* skills. Syntactic awareness concerns the understanding and manipulation of syntactic structures (Layton et al., 1998). The skill has been found to directly predict reading comprehension in children (Cain, 2007) and adults (Guo et al., 2011), suggesting its importance for reading. Importantly, assessments of these capacities are memory-based, and research also shows that reading comprehension (Cain et al., 2004) and syntactic awareness (Cain, 2007) significantly correlate with memory performance. In addition, needing to exercise these skills should increase the difficulty of learning and its effectiveness, as studies on learning show that more difficult recall tasks are more beneficial for future recall than easier tasks (Pyc & Rawson, 2009).

Methods

Procedure

This study was part of a larger research project involving further cue manipulations. Participants completed two blocks of studying and testing. Each block started with a 15-minute learning session in Slimstampen, an adaptive learning software developed to optimize learning based on ACT-R (van Rijn et al., 2009). A two-minute filler task of Tetris followed the learning session. After that, the participants were tested on their understanding of the cue material and had to provide definitions for the studied terms. The process repeated once more with a different set of items. Manipulations of the cues only occurred in the second block. Each participant was only exposed to one of the manipulations.

Slimstampen

Slimstampen is a learning software developed by van Rijn and colleagues (2009). It is based on the ACT-R framework and provides a scheduling algorithm that presents an item to the learner when its predicted activation level is the lowest among all currently studied items. As an adaptive learning system, it adapts the activation decay rate based on the mismatch between predicted and observed response times. New items are presented, if possible, when all currently studied items are above the threshold. Upon item presentation, a textual cue is shown in centred formatting at the screen's centre, and participants are required to type the correct response into a textbox below. Reaction times are measured as the time until the first letter is typed. Feedback including the correct response is given immediately upon submission of an answer.

Items

Items were sampled from the textbook "Cognition: Exploring the Science of the Mind" (Reisberg, 2018) and consisted of 50 terms from cognitive psychology. The terms were randomly divided into two sets of 25 items. Each learning set was only used in one block. The first learning block did not include any manipulations to the cue presentation. For the second block, either an unchanged set was presented, one with an altered spatial layout as an additional cue, or one with a syntactic transformation. The larger experiment that this study was nested in also included a condition with a synonymous alternative. All experimental conditions only had one additional cue variation, making two cue versions per item. The software randomly varied the order in which the items were presented to the learner within a session. Upon the first presentation, the participant was shown all variants of the cues and the correct response. A list of all learning sets and their manipulations can be found in Appendix A.

Cue Manipulations

The spatial layout was manipulated by inserting line breaks into the cues. Each cue only had one line break regardless of cue length. Locations of line breaks were chosen to induce higher variations in spatial layout. No changes were made to the words within the cue.

Syntax was varied via syntactic transformations of of the original cue, such as passivization or changes in the order of a list. The word stem of all words stayed identical for both variants of the cue. Slight changes to the words were made to accommodate the grammatical demands of passivization.

Test

To assess how much of the concept participants remember, they were shown the terms related to the cues they had been studying. Thus, the response during the study session was the cue for the test session. Participants were asked to provide definitions for each term to investigate how much they had processed the cue content during the study session. Responses were graded with partial scores based on a pre-made rubric dividing the cues into their conceptual components. Thus, participants could receive partial points if they recall parts of the term's definition but failed to recall the entire definition. No time constraints were imposed for the test.

To investigate how and whether participants changed their learning behavior in response to having completed the first block, an additional question was included at the end of the study to let participants indicate and describe potential changes in learning strategy.

Participants

Forty-eight students (all aged 18-25) from the University of Groningen were recruited to participate in the research. To qualify, participants needed good English skills and little to no prior experience with cognitive psychology. Participants were semi-randomly assigned to the conditions to ensure similar-sized groups. Informed consent was collected following the guidelines of the ethical committee of the psychology department of the University of Groningen (PSY-2223-S-0355).

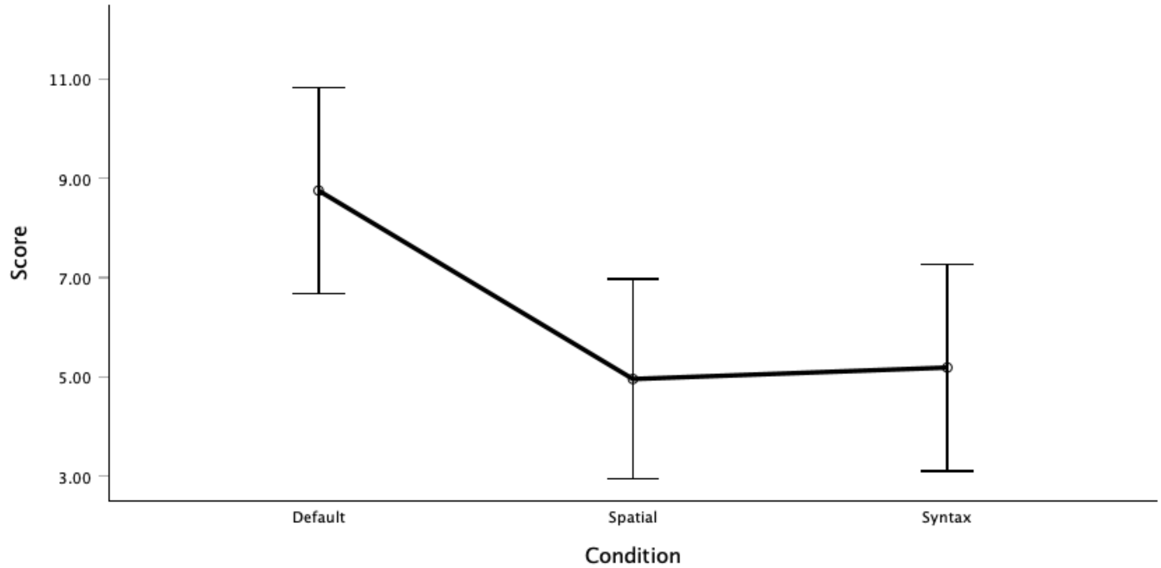
Results

Two out of the 48 participants that completed the study were excluded because they ended their study sessions prematurely. Thus, 46 participants remained, with 15 in the default condition, 16 in the spatial condition, and 15 in the syntax condition.

As Figure 1 shows, baseline data showed a large and significant imbalance between the conditions on raw test scores in the first block ($F(2,43) = 4.242$, $p = 0.021$). ANCOVAs were conducted using first-block scores as covariates to correct for these imbalances as they have been shown to be more robust than change score ANOVAs (Egbewale, 2014). Tukey-corrected post hoc tests were only conducted if the global ANCOVA test showed significant results at the conventional alpha level of 0.5.

Figure 1

Raw Means of First Block Test Scores



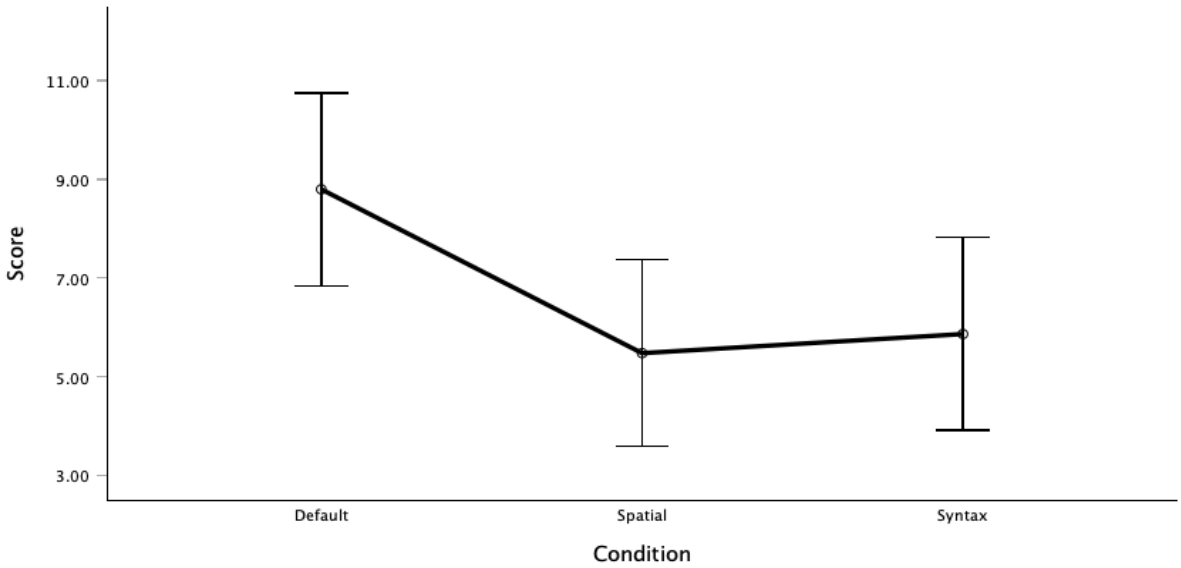
Note: Error bars: +/− 2 SE

Test Performance

Figure 2 shows the raw means, and Figure 3 shows the adjusted means of test scores in the second block across conditions. All groups achieved similar points in the test when adjusting for baseline imbalance, with the default condition (M = 7.14) being slightly higher than the spatial (M = 6.35) and syntax condition (M = 6.59). Accordingly, when adjusting for baseline imbalance using ANCOVA, no significant differences were found in test performance across the different conditions (F(2,42) = 0.292, p = 0.748).

Figure 2

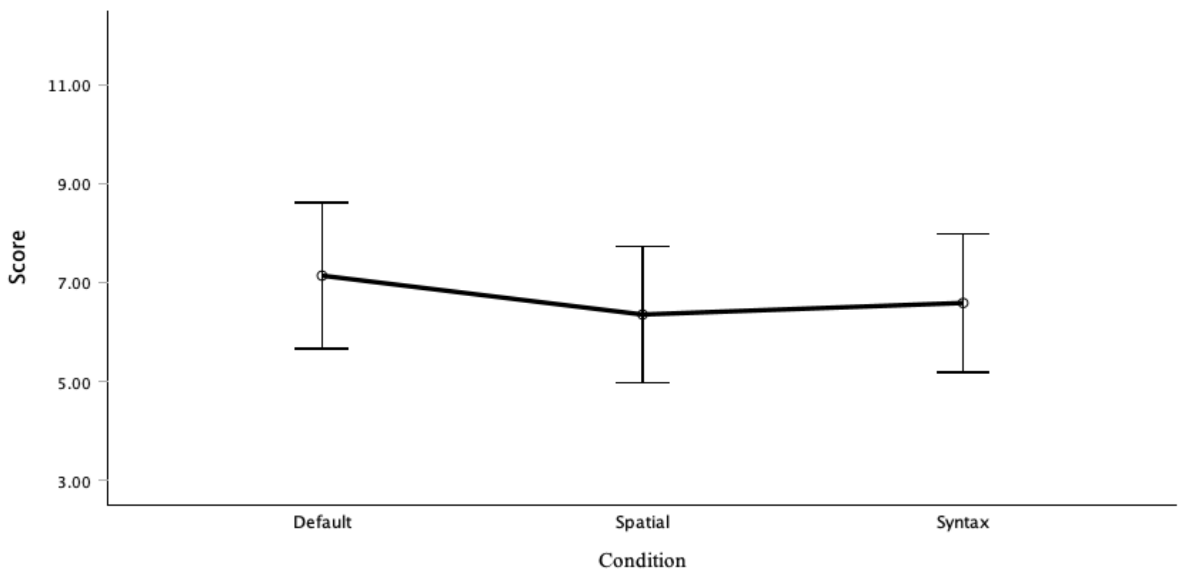
Raw Means of Second Block Test Scores



Note: Error bars: +/− 2 SE

Figure 3

Adjusted Means of Second Block Test Scores



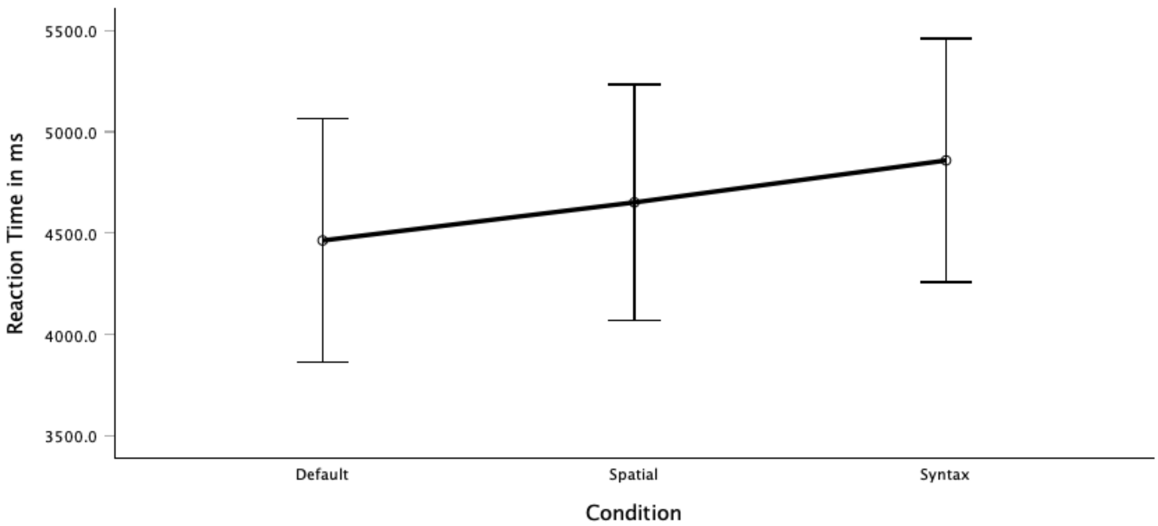
Note: Means are corrected for first block test scores. Error bars: +/− 2 SE

Reaction Time

Figure 4 shows the raw means, and Figure 5 shows the adjusted means of reaction times in the second block across conditions. As with the test scores, similar adjusted reaction times were observed across the conditions, with the default condition being slightly faster (M = 4556ms) than the syntax (M = 4691ms) and spatial condition (M = 4721ms). As an investigation of the assumption showed violations of normality of the residuals, the Kruskal-Wallis test was conducted instead of ANCOVA. Once again, no significant differences were found ($\chi^2(2) = 2.027$, $p = 0.363$).

Figure 4

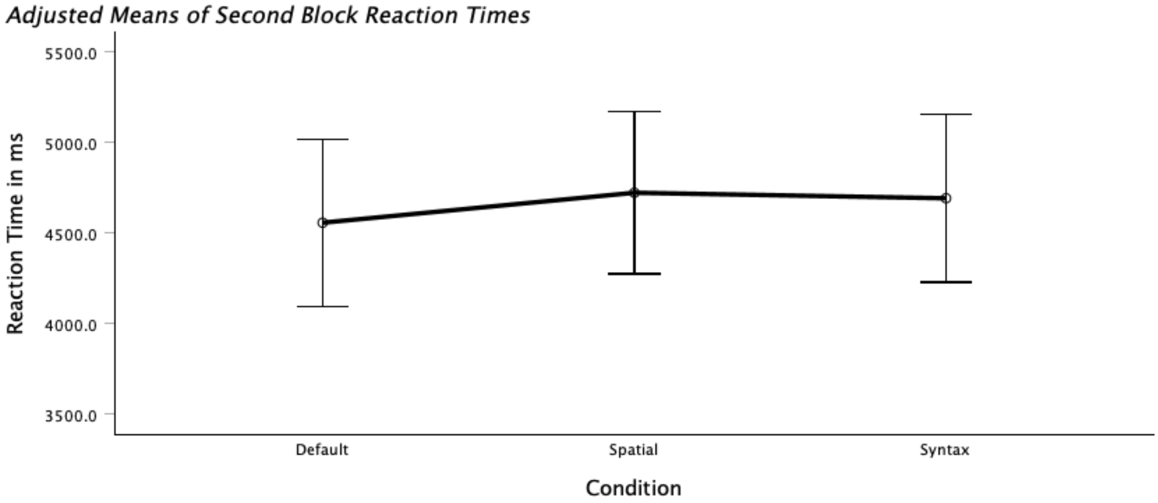
Raw Means of Second Block Reaction Times



Note: Error bars: +/- 2 SE

Figure 5

Adjusted Means of Second Block Reaction Times



Note: Means are corrected for first block reaction times. Error bars: +/- 2 SE

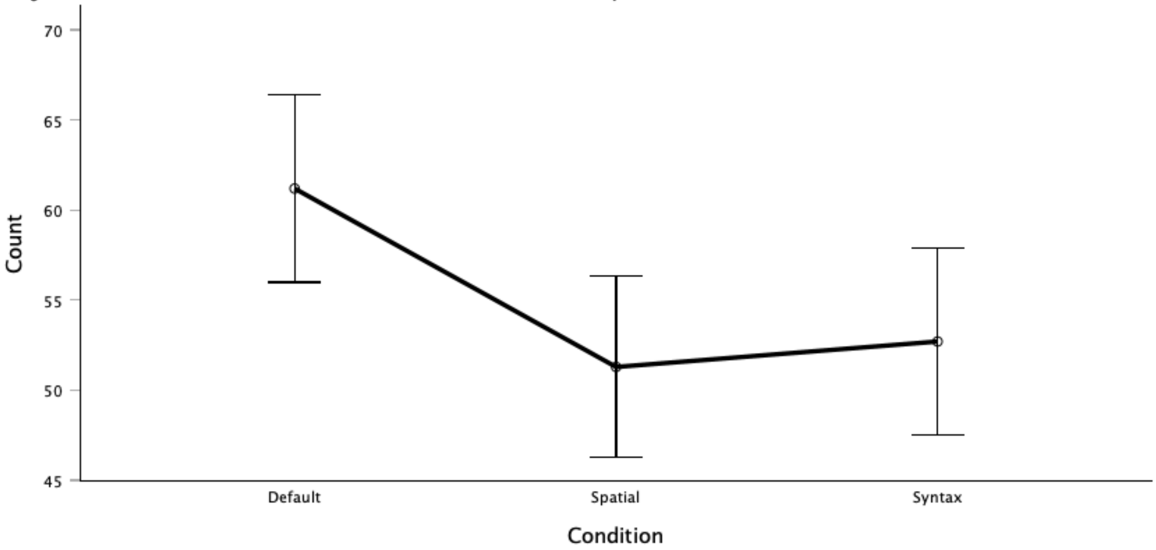
Exploratory Analyses

Exploratory analyses of study behaviour during the Slimstampen session were conducted to see if there were any differences across the conditions. The same approach as in the hypothesis testing was used, with baseline scores as covariates in ANCOVA.

Firstly, the correct responses during the study session were assessed. The adjusted means, as seen in Figure 6, reveal that participants in the default condition (M = 61.2) gave more correct responses than those in the spatial (M = 51.3) and syntax condition (M = 52.7). These differences were significant (F(2,42) = 4.315, p = 0.020). Tukey-corrected post hoc tests revealed significant differences between the spatial and default condition (p = 0.024).

Figure 6

Adjusted Means of Second Block Number of Correct Responses

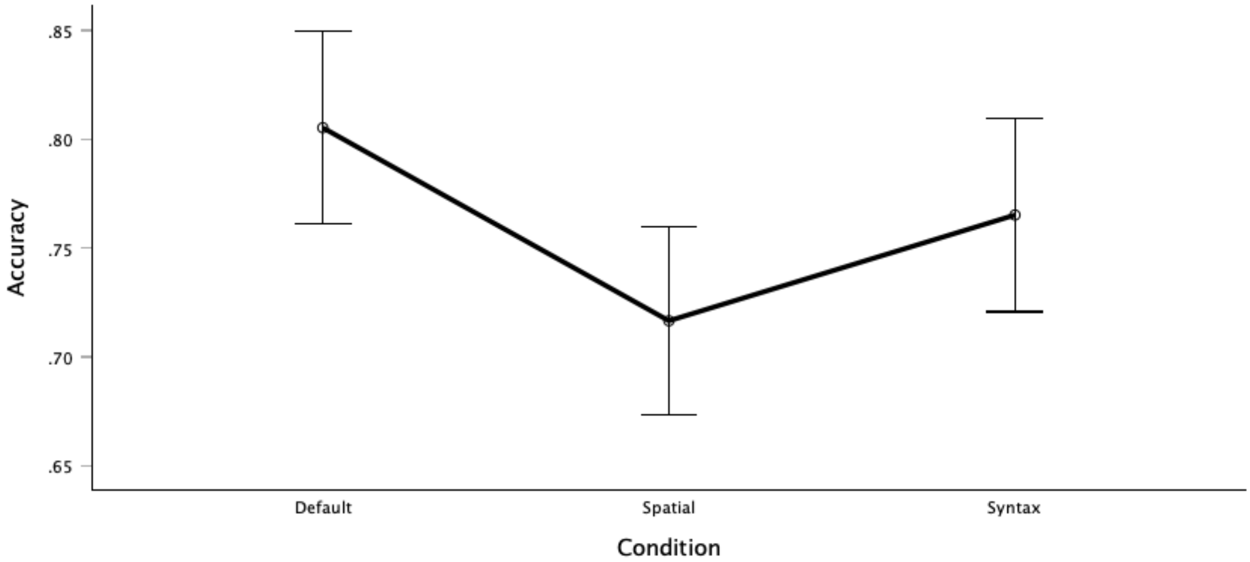


Note: Means are corrected for first block number of correct responses. Error bars: +/− 2 SE

To assess whether these differences were due to the different number of responses given during the learning session, accuracy scores were calculated by dividing the number of correct responses by the number of total responses. Adjusted means of the accuracy scores, as seen in Figure 7, show a similar pattern, with those in the default condition (M = 0.81) being more accurate than those in the spatial (M = 0.72) and syntax condition (M = 0.77). These differences were significant (F(2,42) = 4.098, p = 0.024). Again, Tukey-corrected post hoc tests revealed a significant difference between the spatial and default condition (p = 0.018).

Figure 7

Adjusted Means of Second Block Study Accuracy

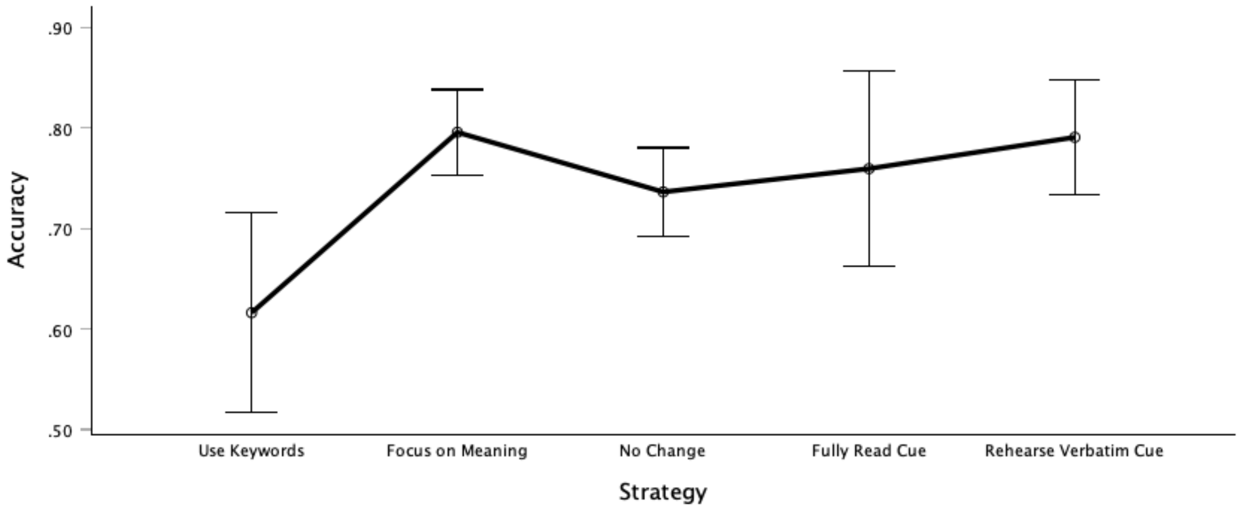


Note: Means are corrected for first block study accuracy. Error bars: +/- 2 SE

Investigations into the changes in study strategy revealed that most people changed strategy (67.4%) after the first block. The most common strategy change with 16 participants across conditions (34.8%) was focusing more on the meaning of the cue. The second most common strategy, aside from those not changing, was to study the verbatim definition presented in the study session with nine participants across conditions (19.6%). Lastly, three participants each reported to either try to select keywords to remember the cue better or to fully read the cues before making decisions (each 6.5 %). The choice of strategy change did not differ significantly across conditions ($\chi^2(8) = 3.909$, p = 0.865). To investigate how the strategy change related to performance, the same analyses were run as before. Unfortunately, due to the low sample size, it was not possible to include both grouping variables, change in strategy and condition. The results only show significant differences in study accuracy (F(4,40) = 3.130, p = 0.025) with the adjusted means of those that changed to rely on (M_{adj}= 0.616) significantly worse (p = 0.017) than those that chose to rely on meaning (M_{adj}= 0.796) and significantly worse ($p = 0.036$) than those that chose to study the verbatim definition ($M_{adj} = 0.791$).

Figure 8

Adjusted Means of Second Block Study Accuracy Across Different Strategy Changes



Note. Means are corrected for first block study accuracy. Error Bars +/- 2 SE

Discussion

The study investigated how superficial contextual information affects concept learning in a digital flashcard environment. It was hypothesized that lowering the predictability of superficial contextual cues via either change in the spatial relationships among words or via syntactic transformations leads to deepened processing of the cue's content, as reflected by increased performance on the post-test. In addition, it was hypothesized that participants would require more time to respond to each item during the study session as they lack the predictive benefit of superficial contextual cues. This study was the first to investigate the effect of superficial contextual cues on learning, connecting previously distinct findings from visual search with those from learning and memory research.

Contrary to the first hypothesis, the results suggest that test performance is unaffected by eliminating superficial contextual cues, at least for short retention periods. These findings do not align with Pyc and Rawson (2009), who suggested that self-testing is more effective with difficult than easier retrieval tasks. In addition, they clarify the relationship between syntax and memory and indicate that the relationship between syntactic awareness and memory reflects an acquired skill rather than a fluctuating variable that can be externally influenced despite the findings that syntactic awareness can be trained (Layton et al., 1998). However, one reason for the lack of an effect could be the measure of test performance employed after the test session. Participants had to provide the definitions rather than the term they studied. Thus, the cognitive processes occurring during studying and testing differed significantly as the available retrieval cues used in the study session were removed. According to the encoding specificity principle (Tulving & Thomson, 1973), retrieval success is determined by matching cognitive processes between encoding and retrieval. As the test reversed the association learned in the study session, the potentially gained strength of association from definition to term may not have translated to the test as the retrieval cues required by this association were unavailable. Thus, the findings align with research on encoding specificity, which may explain the lack of a significant difference. Future studies should investigate alternative measures of cue understanding that do not require a reversal of the learned association. In addition, future studies should look into extending the retention interval as a difference in encoding may instead be reflected in a difference in the durability of the trace rather than short-term accessibility.

Furthermore, the data did not support the second hypothesis of increased reaction times, as no significant difference in reaction times was found across conditions. Firstly, this finding may suggest that superficial contextual information is not a relevant retrieval cue during study sessions in flashcard learning. However, exploratory analyses have shown that learners may use them, although to a lesser degree than predicted, as those with varied spatial layouts suffered from accuracy deficits. Notably, the typical finding of decreased reaction times in contextual cueing studies (Chun & Jiang, 1998) was not seen, suggesting that contextual cues neither speed up cognitive processes via attentional orienting nor response facilitation in flashcard learning.

In addition, syntactic transformations did not affect reaction times, perhaps reflecting that definitions are encoded predominantly on a semantic level with little syntactic information. These suggestions are supported by early studies from Mehler (1963) and Sacks (1967), which both reported that people tend to simplify sentence representations on a syntactic level and fail to remember the exact syntactic structure of a sentence accurately.

Similarly, the lack of an effect on reaction times could also reflect the availability of keywords as predictive cues in all conditions. None of the experimental manipulations significantly alternated the words used in the cues aside from slight changes to the word in the syntax condition. Thus, participants might have been able to remember specific term-definition pairs by using disambiguating words within the cues. Interestingly, only a few participants reported a change in strategy towards focusing on keywords and those that did change to keywords performed significantly worse during the study session. However, it is important to note that the question reflected changes in strategy rather than the individual strategies used in each block. Thus, it could be that significantly more people relied on keywords in both sessions and that those that indicated a change use keywords less efficiently. Future studies could use eye-tracking devices to investigate whether and how participants may preferentially focus on disambiguating keywords. In addition, visual masks (i.e. substituting all letters by x's for a specific amount of time) that hide any semantic information while keeping spatial information available could be used in some trials to assess how learners may benefit from contextual information on a more detailed level than mere reaction times. Thus, while evidence on reaction times in the study points towards no usage of contextual information in flashcard learning, findings on accuracy rating suggest that further investigations into these dynamics are warranted.

Limitations

However, the study's limitations should be considered when judging these results. These primarily concern the design used by the study as well as statistical corrections. Firstly, the heavy baseline imbalances found in the first block test scores might have introduced an additional factor impacting the effect of superficial contextual information. As the default condition outperformed all experimental conditions in the first block, the distinction between the default and the experimental blocks also becomes a differentiation between high performers and low performers which may have potentially suppressed any existing effects. For example, it might be that high performers are more affected by the experimental manipulations as they learn more efficiently by using the heuristics provided by contextual cues. However, most high performers were in the default group, not exposed to experimental manipulations. In addition, despite the statistical corrections made by ANCOVA, these come at the cost of degrees of freedom due to the added covariate. Avoiding these imbalances by using larger samples or by matching participants would be the optimal choice for future studies. Larger samples would also help investigate the role of strategy changes, as it was not possible to conduct an ANCOVA analysis of the relationship between strategy changes and the experimental manipulations. In addition, future research should look into the qualities distinguishing high from low performers in digital flashcard settings to investigate how their approaches to learning differ.

Secondly and more problematically, the measure of test performance was reactive and led to changes in various changes in learning strategies in addition to the changes imposed by the experimental manipulations. Even participants in the default condition indicated changes in their strategy, suggesting that many of these changes were not due to the experimental manipulations but rather the test format. It might be that these changes in strategy may have triggered similar effects as the experimental manipulations, overshadowing their impact. The shift in strategy may have helped participants in the default condition adapt their performance in a top-down manner rather than the bottom-up manner induced by the experimental modifications. Unfortunately, it was not possible to investigate any potential interactions between the conditions, the choice of strategy, and the performance level of participants due to the low number of participants.

The more likely reason for the lack of an effect on test performance is the insensitivity of the test measure, as it assumes that associations learned in one direction can easily be reversed. As research on encoding specificity suggests, this is unlikely to be the case making the test measure less sensitive to changes in cue processing. Future studies should aim to develop better measures of cue comprehension that do not rely on drastically different cognitive processes in the test compared to the study session. One potential solution may be recognition tasks with slightly semantically altered versions of cues that participants.

Lastly, it was identified that the spatial condition was missing the spatial variation of one term. However, it is unlikely that this significantly affected the study results as participants did not tend to see all items during the session and it only affected a single item. Thus, the relative impact of this shortcoming is likely to be small.

Conclusion

This study was the first to investigate the impact of superficial contextual cues on the learning process in digital flashcards. It was hypothesized that lowering the predictability of contextual information increases reaction times in study sessions and improves performance in test sessions. The findings suggest that while there are differences in how people study in response to variations in cues, though only in the accuracy of their answers, these differences do not translate to test performance. Alternative explanations could be the short retention interval used by the study or the changes in cognitive processes required by the test. The lack of a finding regarding reaction times could also be due to the availability of keywords. Future studies should further investigate how variations in contextual information impact learning in addition to fixing the limitations of the current study.

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Appendix A

Table A1

Items and Cue Version Used in Each Block

	Block 2								
	Monocular Distance Cues	Reversible/ambiguous Figure	Size Constancy	Visual Search Task	Pictorial Cues	Priming	Excitatory Connection	Mask	Bigram Detectors
Default	Features of the visual stimulus that indicate distance even if the stimulus is viewed with only one eye.	Drawings that can be readily perceived in more than one way.	The achievement of perceiving the constant size of objects despite changes in the size of the retinal image due to variations in viewing distance.	An often-used laboratory task in which research participants are asked to search for a specific target, such as a shape, within a field of other stimuli.	Patterns that can be represented on a flat surface to create the sense of a three-dimensional object or scene.	A process through which one input or cue prepares a person for an upcoming input or cue.	A link from one node or detector, to another, such that activation of one node activates the other.	A visual presentation that is used to interrupt the processing of another visual stimulus.	Hypothetical units in a recognition system that respond, or fire, whenever a specific letter pair is in view.
Spatial	Features of the visual stimulus that indicate distance even if the stimulus is viewed with only one eye.	Drawings that can be readily perceived in more than one way.	The achievement of perceiving the constant size of objects despite changes in the size of the retinal image due to variations in viewing distance	An often-used laboratory task in which research participants are asked to search for a specific target, such as a shape, within a field of other stimuli.	Patterns that can be represented on a flat surface to create the sense of a three-dimensional object or scene.	A process through which one input or cue prepares a person for an upcoming input or cue.	A link from one node or detector, to another, such that activation of one node activates the other.	A visual presentation that is used to interrupt the processing of another visual stimulus.	Hypothetical units in a recognition system that respond, or fire, whenever a specific letter pair is in view.
Syntax	Even if the stimulus is viewed with only one eye, these features of the visual stimulus indicate distance.	n more than one way can these drawings be readily perceived.	Despite variations in viewing distance leading to changes in the size of the retinal image, perceiving the constant size of objects is achieved.	Research participants are asked to search for a specific target, such as a shape, within a field of other stimuli, in this often-used laboratory task.	Creating the sense of a three-dimensional object or scence through these patterns that can be represented on a flat surface.	A person is prepared for an upcoming input or cue through one input or cue in this process.	Activation of one node or detector activates the other via this link from one node or detector to another.	Interrupting the processing of another visual stimulus by using this visual presentation.	Whenever a specific letter pair is in view, these hypothetical units in a recognition system respond or fire.
Grading	a) cues from stimulus indicating distance, b) only requires monocular vision	a) drawings/images can be easily perceived in multiple ways	a) constant size is perceived even though b) retinal image changes	a) participants asked to search for target among b) distractors or other stimuli	a) 2D patterns that can imitate 3D image	a) input cue prepares for upcoming input/cue (not exclusively rep. priming)	a) link between detectors/nodes b) activate each other	a) visual presentation b) used to iinterrupt processing	a) detectors firing in response to letter pairs

Block 2

	Bottom-up Processing	Top-down Processing	Transcendental Method	Serial Processing	Introspection	Behaviorist Theory	Gestalt Principles	Unconscious Inference	Well-Formedness	Recognition by Components Model	Feature Net
Default	A sequence of events or processes that is governed by the stimulus input itself. Often referred to as data-driven.	A sequence of events or processes that is heavily shaped by the knowledge and expectations that the person brings to the situation.	A type of theorizing proposed by the philosopher Immanuel Kant. An investigator first observes visible effects and then infers the invisible processes that lead to these effects.	A system in which only one step happens at a time such that the steps occur in a series.	The process through which one looks within to observe and record the contents of one's own mental life.	Broad principles concerned with how behavior changes in response to different configurations of stimuli, such as rewards and punishments. It sought to avoid mentalistic terms,	A number of rules that seem to govern observers' organization of visual input, grouping some elements together but perceiving other elements to be independent of one another.	The hypothesized steps that perceivers follow to take one aspect of the visual scene, such as viewing distance, into account in judging another aspect, such as size	A measure of the degree to which a string of symbols, such as letters, conforms to the usual patterns, such as the rules of spelling.	A model of object recognition of hypothesized basic building blocks out of which all the objects we recognize are constructed.	System for recognizing patterns that involves a network of detectors. Detectors for features are the initial layer in the system.
Spatial	A sequence of events or processes that is governed by the stimulus input itself. Often referred to as data-driven.	A sequence of events or processes that is heavily shaped by the knowledge and expectations that the person brings to the situation.	A type of theorizing proposed by the philosopher Immanuel Kant. An investigator first observes visible effects and then infers the invisible processes that lead to these effects.	A system in which only one step happens at a time such that the steps occur in a series.	The process through which one looks within to observe and record the contents of one's own mental life.	Broad principles concerned with how behavior changes in response to different configurations of stimuli, such as rewards and punishments. It sought to avoid	A number of rules that seem to govern observers' organization of visual input, grouping some elements together but perceiving other elements to be independent of one another.	The hypothesized steps that perceivers follow to take one aspect of the visual scene, such as viewing distance, into account in judging another aspect, such as size.	A measure of the degree to which a string of symbols, such as letters, conforms to the usual patterns, such as the rules of spelling.	A model of object recognition of hypothesized basic building blocks out of which all the objects we recognize are constructed.	System for recognizing patterns that involves a network of detectors. Detectors for features are the initial layer in the system.
Syntax	The stimulus input itself governs this sequence of events/processes, that is often referred to as data-driven.	Knowledge and expectations that the person brings to the situation heavily shape this sequence of events/processes.	The philosopher Immanuel Kant proposed this type of theorizing. An investigator infers the invisible processes that lead to effects, after first having observed them.	Steps in this system occur in a series because only one step happens at a time.	Observing and recording the contents of one's own mental life by looking within during this process.	How behavior changes in response to different configurations of stimuli, such as punishments and rewards, concerns these broad priniciples. Mentalistic terms,	Oberver's organization of visual input, perceiving some elements to be independent of one another but grouping others together, seems to be governed by this number of rules.	Perceivers follow these hypothesized steps to judge one aspect of a visual scene, such as size, taking into account another aspect, such as viewing distance.	The degree of conformity to a usual pattern of symbols, such as the rules of spelling, is measured for a string of symbols, such as letters.	Hypothesized basic building blocks are used to construct all the objects we recognize in this model of object recognition	The initial layer in this system for recognizing patterns, involving a network of detecors, are detectors for features.
Grading	a) sequence of events/processes, b) governed by the stimulus, c) data driven	a) sequence of events processes b) shaped by knowledge/expectations c) brought by individual	a) method of theorizing, b)Kant,c)first observes visible then infers the invisible cause	a) system in which one step happens at a time	a) process/act of looking within b) observe/record contents of one's own mental life	a) broad principles, b) behavior changes with varied configurations of stimuli(r/p)i, c) avoid mentalistic terms(examples)	a) rules b) organization, c) grouping elements d) other elements independent	a) hypothesized steps b) take one aspect of scene c) to judge another	a) measurement, b) string of symbols (example), c) fits pattern	a) model of object recognition, b) hypothesized building blocks c) all objects built from these blocks	a) system for recognizing patterns

	Blockl 1					Block 2				
	Activation Level	Perceptual Constancy	Neural Synchrony	Figure/Ground Organization	Response Threshold	Response Time	Clinical Neuropsycholog y	Brightness Constancy	Distributed Representation	Binocular Disparity
Default	A measure of the current status for a node or detector.	The achievement of perceiving the constant properties of objects despite changes in the sensory information due to changes in our viewing circumstances.	A pattern of firing by neurons in which neurons in one brain area fire at the same time as neurons in another area indicating that they respond to the same stimulus	The processing step in which the perceiver determines which aspects of the stimulus belong to the central object and which aspects belong to the background	The quantity information or activation needed to trigger a response.	The amount of time needed for a person to respond to a particular event.	The scientific study of brain function that mainly uses cases in which damage or illness has disrupted the working of some brain structure.	The achievement of perceiving the constant brightness of objects despite changes in the light reaching the eye due to variations in illumination.	A representation in which ideas or contents are represented by a pattern of activation across a wide number of nodes.	A distance cue based on the differences between the two eyes' views of the world. This difference becomes less pronounced the farther away an object is from the observer.
Spatial						*	The scientific study of brain function that mainly uses cases in which damage or illness has disrupted the working of some brain structure.	The achievement of perceiving the constant brightness of objects despite changes in the light reaching the eye due to variations in illumination.	A representation in which ideas or contents are represented by a pattern of activation across a wide number of nodes.	A distance cue based on the differences between the two eyes' views of the world. This difference becomes less pronounced the farther away an object is from the observer.
Syntax						A person needs this amount of time after a particular event to respond.	Cases in which the working of some brain structure has been disrupted by damage or illness are mainly used by this scientific study of brain function.	Despite variations in illumination that cause changes in the light reaching the eye, the perception of constant brightness of objects is achieved.	A pattern of activation across a wide number of nodes represents ideas or contents in this representation.	Using the difference between the two eyes' views of the world, which becomes less pronounced the farther away an object is from the observer, as a distance cue.
Grading	a) mentions activity/status b) mentions it is for nodes/detectors/ neurons	a) mention that properties/featur es are perceived the same b) that this occur even when viewing circumstances/co nditions change	a) mention synchronous firing of neurons b) mentions that they can be in different regions/parts of brain c) mention that it indicates they are	a) mention it concerns distinction between background and stimulus b) mention it is a step in processing/perce ption	a) mention that it needs to be met for a response/reactio n b) mention that it concerns activation and/or information/inpu t	a) time need/required to respond to event/stimuli	a) brain function b) cases of damage/illness c) disrupted function in brain	a) perceived constant brightness b) despite changes in light entering eye	a) representation of ideas/contents b) represented by pattern c) across nodes	a) distance cue b) differences between eyes c) less pronounced with distance

Block 1

	Neuroimaging Techniques	Word Superiority Effect	Recency	Parallel Processing	Conjunction Error	Optic Flow	Shape Constancy	Linear Perspective	Cognitive Neuroscience	Inhibitory Connection	Interposition
Default	Noninvasive methods for examining either the structure or the activation pattern within a living brain.	The data pattern in which research participants are more accurate and more efficient in recognizing words and wordlike letter strings than they are in recognizing individual letters.	Whether a detector or node has been activated in the recent past.	A system in which many steps are going on simultaneously.	An error in perception usually due to attention's overload in which a person correctly perceives what features are present but misperceives how the features are joined.	The pattern of change in the retinal image in which the image grows larger as the viewer approaches an object and shrinks as the viewer retreats from it.	The achievement of perceiving the constant shape of objects despite changes in the shape of the retinal image due to variations in viewing angle.	A cue for distance based on the fact that parallel lines seem to converge as they get farther away from the viewer.	The scientific study of the brain and the nervous system to understand humans' mental functioning.	A link from one node, or detector, to another, such that activation of one node decreases the activation level of the other.	A monocular distance cue that relies on the fact that objects farther away are blocked from view by closer objects that happen to be in the viewer' s line of sight.
Spatial											
Syntax											
Grading	a) mention that it can be used for structure/activati on pattern b) mention that they are noninvasive/non-damaging	a) mention word recognition over letter recognition b) mention that it improves RT and accuracy	a) mention that it concerns detectors/nodes/ neurons b) mention that it concerns recent activation	a) mention that steps happen in parallel/concurrently/ simultaneously	a) mention it concerns perception b) mention the role of attention c) mention that it concerns the binding/joining of features	a) mention it concerns changes in retinal image/sensation b) mention direction of changes correctly	a) mention perception of constant shape b) mention that happen despite changes in retinal image/sensation/ input	a) mention that it is distance/depth cue b) mention that it is based on converging lines	a) mention it is a study/field and mention it concerns the nervous system and/or brain c) mention that it aims to understand mental	a) mention that it is a link between nodes/detectors/ neurons b) mention that activation of one decreases activation of other	a) mention it is a distance cue b) mention it is based on information about blocked objects

	Block 1								
	Visual Features	Viewpoint-Independent Recognition	Geon	Motion Parallax	Repetition Priming	Tachistoscope	Distance Cues	Binding Problem	Local Representation
Default	The constituents of a visual pattern - vertical lines, curves, diagonals, and so on - that, together, form the overall pattern.	A process in which the ease or success of recognition does not depend on the perceiver's particular viewing angle or distance with regard to the target object.	One of the basic shapes proposed as the building blocks of all complex three-dimensional forms.	A distance cue based on the fact that as an observer moves, the retinal images of nearby objects move more rapidly than of objects farther away.	A pattern of priming that occurs simply because a stimulus is presented a second time; processing is more efficient on the second presentation.	An old device that allows the presentation of stimuli for precisely controlled amounts of time.	Information available that allows the perceiver to judge an object's position.	The problem of reuniting the various elements of a scene, given that these elements are initially dealt with by different systems in the brain.	A representation in which information is encoded in some small number of identifiable nodes
Spatial									
Syntax									
Grading	a) mention that they are the parts of a visual pattern/stimulus b) give an example	a) mention independence of object recognition from perspective to target	a) mention that they are shapes/blocks b) mention that they make up all complex forms/objects	a) indicate it is a distance cue b) describe that it is a difference in retinal image/sensation of movement c) mention direction of perceived motion	a) mention that it is based on repeating presentations b) mention that processing gets faster/more efficient	a) mention it is used to present stimuli b) mention that interval/speed of presentation can be controlled c) that it is an (old) device	a) mention that it describes cues/info that allow to judge position/depth/distance of object	a) mention that different elements/aspects are processed differently by brain b) mention that it concerns binding of separate processes	a) mention that encoding/representation of information b) is only in small number of identifiable nodes/not spread across multiple nodes

Note. Lack of Spatial Variation for Item "Response Time" was only identified after study.

Appendix B

Table B1

Descriptive Statistics of Participant Performance in Both Blocks Across Conditions

		Default (N = 15)		Spatial (N = 16)		Syntax (N = 15)	
Variable	Block	M	SD	M	SD	M	SD
Score	1	8.756	4.466	4.958	3.560	5.189	4.041
	2	8.797	4.519	5.475	3.166	5.863	3.576
RT	1	4132.867	955.047	4159.799	1016.027	4444.167	727.226
	2	4463.300	1442.879	4651.156	1070.947	4858.333	924.533
Correct	1	60.800	19.542	59.688	14.700	59.933	10.003
	2	61.533	15.273	51.063	13.493	52.600	7.827
Accuracy	1	0.749	0.171	0.710	0.094	0.753	0.104
	2	0.811	0.080	0.705	0.117	0.772	0.104

Table B2

ANCOVA *Results of Condition per Variable Controlling for First Block Measure*

Variable	F(2,42)	p	Eta-Partial-Squared
Score	0.292	0.748	0.014
Reaction Time	2.027*	0.363*	NA
Correct	4.315	0.020	0.170
Accuracy	4.098	0.024	0.163

Note. ANCOVA uses first block scores as covariate. * For Reaction Time, the test statistic and p-value refer to the Kruskal-Wallis test.

Table B3

Post Hoc Tests for Number of Correct Responses by Condition

Condition 1	Condition 2	Difference	t	p_{Tukey}
Default	Spatial	9.903	2.737	0.024
	Syntax	8.491	2.310	0.065
Spatial	Syntax	-1.412	-0.390	0.920

Table B4

Post Hoc Tests for Study Accuracy by Condition

Condition 1	Condition 2	Difference	t	p_{Tukey}
Default	Spatial	0.089	2.857	0.018
	Syntax	0.040	1.282	0.413
Spatial	Syntax	-0.049	-1.564	0.273

Note. Differences are calculated by subtracting condition 2 from condition 1.

Table B5

Contingency Table of Strategy Change by Condition

	Strategy Change					
Condition	Keywords	Meaning	None	Reading	Verbatim	Total
Default	1	7	4	1	2	15
Spatial	1	3	6	1	5	16
Syntax	1	6	5	1	2	15
Total	3	16	15	3	9	46

Table B6

Chi-Square Test Results for Strategy Change by Condition

	Value	df	p
X^2	3.909	8	0.865
N	46		

Table B7

ANCOVA Results per Strategy Change Controlling for First Block Measures

Variable	F(4,40)	p	Eta-Partial-Squared
Score	1.459	0.233	0.127
RT	0.821	0.520	0.076
Correct	1.433	0.241	0.125
Accuracy	3.130	0.025	0.238

Table B8

Post Hoc Tests for Study Accuracy by Strategy Change

Strategy 1	Strategy 2	Difference	t	p_{Tukey}
None	Keywords	0.120	2.244	0.185
	Meaning	-0.059	-1.923	0.322
	Reading	-0.023	-0.437	0.992
	Verbatim	-0.054	-1.489	0.576
Keywords	Meaning	-0.179	-3.282	0.017
	Reading	-0.143	-2.085	0.246
	Verbatim	-0.174	-2.987	0.036
Meaning	Reading	0.036	0.679	0.960
	Verbatim	0.005	0.141	1.000
Reading	Verbatim	-0.031	-0.550	0.981

Note. Differences are calculated by subtracting Strategy 2 from Strategy 1.