Acta Psychologica 211 (2020) 103190

Contents lists available at ScienceDirect

Acta Psychologica

journal homepage: www.elsevier.com/locate/actpsy

Episodic and semantic memory processes in the boundary extension effect: An investigation using the remember/know paradigm

Lisa M.E.C. van den Bos[a,*], Jeroen S. Benjamins[a,b], Albert Postma[a]

[a] Experimental Psychology, Helmholtz Institute, Utrecht University, the Netherlands
[b] Social, Health and Organizational Psychology, Utrecht University, the Netherlands

ARTICLE INFO

Keywords:
Boundary extension
Semantic memory
Episodic memory
Remember/know paradigm

ABSTRACT

Background: Boundary extension (BE) is a phenomenon where participants report from memory that they have experienced more information of a scene than was initially presented. The goal of the current study was to investigate whether BE is fully based on episodic memory or also involves semantic scheme knowledge.

Methods: The study incorporated the remember/know paradigm into a BE task. Scenes were first learned incidentally, with participants later indicating whether they remembered or knew that they had seen the scene before. Next, they had to rate 3 views - zoomed in, zoomed out or unchanged - of the original picture on similarity in closeness in order to measure BE.

Results: The results showed a systematic BE pattern, but no difference in the amount of BE for episodic ('remember') and semantic ('know') memory. Additionally, the remember/know paradigm used in this study showed good sensitivity for both the remember and know responses.

Discussion: The results suggest that BE might not critically depend on the contextual information provided by episodic memory, but rather depends on schematic knowledge shared by episodic and semantic memory. Schematic knowledge might be involved in BE by providing an expectation of what likely lies beyond the boundaries of the scene based on semantic guidance.

GEL classification: 2343 learning & memory

1. Introduction

Episodic memory is usually thought to encompass information about a temporal localised change in the world, such as "he was running", and information about the external context of the event, such as where and when it took place (Gardiner & Java, 1991; Knowlton & Squire, 1995; Tulving, 1993). Recollecting the spatiotemporal context is what distinguishes episodic memory from semantic memory and the act of simply recognising an object. Notably, the literature on episodic memory has shown that an interesting error can occur when people recall a previously seen scene. Observers consistently report having seen more of the scene than originally shown. Particularly areas that fall outside of the physical boundaries of the viewed scene are sensitive to this error. This error in memory has come to be known as boundary extension (BE; Intraub & Richardson, 1989). Extra information that observers typically report may encompass objects or backgrounds that might have been present beyond the boundaries of the scene, but were not visible (Park et al., 2007).

Although BE can be regarded as an error in memory, it may serve a supportive function for scene perception (Intraub, 2012; Intraub & Dickinson, 2008). BE may lead to a more continuous perceptual experience of one's surroundings by facilitating the integration of successive sensory input. Support for this claim comes from the fact that BE only arises when the image contains a scene or objects that together form a scene, as opposed to images with objects that do not form a scene (Gottesman & Intraub, 2002; Intraub et al., 1998). Castelhano et al. (2018) describe a scene either as collection of related elements or as a hierarchical structure providing a scaffold in which elements can be integrated. A scene involves a continuous spatial layout in which an object can be incorporated. The spatial layout of a scene refers to the internal representation of the way in which objects and landmarks are positioned in space (Evans, 1980; Spencer et al., 1989). An image in which objects form a scene can, for example, contain palm trees, the beach, a lounge chair with the sea in the background. On the other hand, a palm tree, toothbrush, and a television set randomly placed on a blank background do not make a scene. It is thought that BE occurs because humans are not limited to the direct sensory input from the eyes, but also possess an implicitly constructed internal representation of the scene. Because we automatically extend beyond the physical

* Corresponding author at: Utrecht University, Heidelberglaan 1, 3584 CS Utrecht, the Netherlands.
E-mail address: m.e.c.vandenbos@uu.nl (L.M.E.C. van den Bos).

https://doi.org/10.1016/j.actpsy.2020.103190
Received 21 May 2020; Received in revised form 31 August 2020; Accepted 24 September 2020
Available online 30 October 2020

edges of the scene, we incorporate this extended context into our internal representation of the scene. When the original picture is shown again, we compare the extended internal representation to the picture, which is then perceived as being too close (Intraub, 2012). Extrapolating beyond the available information occurs in all senses (not just vision) in order for our brain to make predictions about the external world (Friston, 2010).

Even though BE has been demonstrated to occur in several different populations and circumstances (e.g.: Candel et al., 2004; Seamon et al., 2002), it is unclear to what extent semantic modes of memory retrieval are involved, next to episodic memory mechanisms. For instance, semantic scheme knowledge encompasses general knowledge of scenes which might result in BE, be it to a lesser extent than episodic memory. This is based on evidence that suggests that episodic memory is a prerequisite in order for BE to occur (see e.g. Mullally et al., 2012). Concordantly, though the initial extrapolation of the boundaries of the scene occurs the first time we see the scene, the actual BE error occurs when we later recall the scene as more zoomed out than the original (Bainbridge et al., 2019; Intraub, 2012). However, not much is known about whether BE is uniquely related to episodic memory retrieval, whether it also comprises of a component of semantic memory retrieval, or whether it is related to a general declarative memory mechanism shared by both episodic and semantic memory.

The aim of the present study was to examine whether BE exclusively occurs in relation to episodic memory or alternatively whether it also occurs in semantic modes of memory retrieval. We set out to investigate this by using the remember/know paradigm (Tulving, 1985). In the original technique, the remember/know task was designed to identify episodic (remember judgments) and semantic (know judgments) memories. 'Remember responses' referred to the experience of mental time travel, or self-recollection, which is an important aspect of episodic memory. Recollection of a previously seen item is part of recognition, and thus a part of remembering (Gardiner & Java, 1993). On the other hand, 'knowing' refers to conceptual knowledge, or the representations of concepts people have acquired (see e.g.: Yee et al., 2017). Knowing includes general facts about the world without reference to the circumstances in which they were acquired (Yee et al., 2013), for instance that grass is green or that a coat keeps you warm in the winter, as well as schematic representations of events based upon lifelong experiences (Renoult et al., 2019). Knowing, does not contain recollections and is defined as familiarity without self-recollection, which corresponds to a more semantic based type of memory (Gardiner, 2001; Tulving, 1985). Note that familiarity in the current study refers to the extent in which conceptual processes linked to semantic memory play a role in familiarity-based recognition (Wang & Yonelinas, 2012a; Wang & Yonelinas, 2012b). The remember/know paradigm mostly has been used in recognition tests, though it may also be used in free and cued recall where a high level of episodic trace information results in remember responses accompanied by self-recollection (Hamilton & Rajaram, 2003; Tulving, 1985). In addition, know responses are reported for free recall tests as well, suggesting that free recall is not just driven by conscious recollection shortly after study (see also McDermott, 2006; Mickes et al., 2013).

We should mention here that there has been considerable discussion about whether remembering and knowing are driven by a dual-process model or rather reflect a single-process model (see for example: Wixted & Mickes, 2010; Morris & Rugg, 2004; Yonelinas & Parks, 2007). The dual process model states that there are two more or less distinct manners of memory retrieval. This claim is supported by observations of separate neural circuitries and by the finding that know responses have a similar levels of confidence and accuracy as remember responses (Mickes et al., 2013). A single process model typically assumes a division in terms of strength with remembering comprising stronger memories. Interestingly, in their recent review of the episodic-semantic distinction Renoult et al. (2019) point out that the neural overlap between episodic memory and semantic memory is considerable and that the two types of memory are highly related. At the same time these authors also emphasise that there still remains an extent of distinctiveness. It is beyond the scope of the current research to further address whether episodic and semantic memory are fully dissociated or rather form the opposite ends of a declarative memory continuum, with recollection being contextualised retrieval and with familiarity to be more a form of non-contextual memory. We return on this point in the discussion.

In the present study, participants had to first indicate whether they had a sense of recollection or familiarity when cued by a small section of a previously studied scene. Participants were asked whether the small section of the scene was new, and belonged to a scene they had not seen before, or whether it was old and they had seen it before. When they answered old they had to specify whether it was 'old remember' or 'old know', thereby establishing a distinction between episodic and semantic modes of memory retrieval, respectively. However, this method has also been criticised in the literature (see e.g.: Dunn, 2004, 2008; Wixted, 2007). Alternative methods include adding a confidence measure, to distinguish various levels of confidence during the task (see e.g. Wixted & Mickes, 2010), or by adding a "guess" option for participants to choose instead of remember or know (Migo et al., 2012). By adding a "guess" option, remember and know responses better reflect representations of recollection and familiarity, instead of simply levels of confidence. However, the number of decisions participants had to make was already quite high, hence we decided to keep the remember/know task as simple as possible. Importantly, the current remember/know procedure has proven to be a valid method to distinguish a subjective sense of recollection from familiarity, and is therefore often used in other studies with complex questions to asses memory (see e.g.: Frithsen et al., 2019; Lutz et al., 2017; Schwedes et al., 2019).

Following the remember/know question, participants next had to scale the full scene according to how they remembered it. Evidence has shown that a spatial layout is an important prerequisite for BE (Gottesman & Intraub, 2002), so one can expect that the spatiotemporal aspect of episodic memory may lead to a larger BE effect in remember responses. Mullally et al. (2012) found that patients with impairments in episodic memory, who suffered from selective bilateral hippocampal damage and amnesia, showed significantly less BE than healthy controls on two separate BE tasks. These findings suggest that episodic based memory might play an important role in order for BE to occur. As such we might expect that BE would be larger in cases of episodic based retrieval than in cases of semantic based retrieval. Distinguishing between BE in episodic and semantic memory provides more insight on the functional aspect of BE. Finding stronger BE in episodic memory might suggest that the feeling of recollection depends on the ability to engage in imaginations of the relevant scenes. In contrast, if more BE occurs in semantic memory it would indicate that BE is at least partly driven by schematic spatial knowledge.

2. Method section

2.1. Participants

In this study, 36 participants were tested. All participants were over the age of 18 ($M = 22.3$, $SD = 2.5$), with most of them studying for their Bachelor's or Master's degree (72.2% and 25.0%, respectively) at the Utrecht University. One participant attended the Utrecht University of Applied Sciences (HU: 2.8%). Of the participants, 30 were female and 6 were male. Participants who took medication that influenced their memory or attention, or who suffered from a condition that affected these domains, were not able to participate in the study. All participants had normal eyesight or eyesight corrected to normal (i.e. with glasses/lenses). Participants were recruited via the university's recruitment system (SONA), posters, flyers, and the Utrecht University paid studies Facebook page. Via all recruitment methods, participants were asked to send an email to the provided researcher's email address. They had to

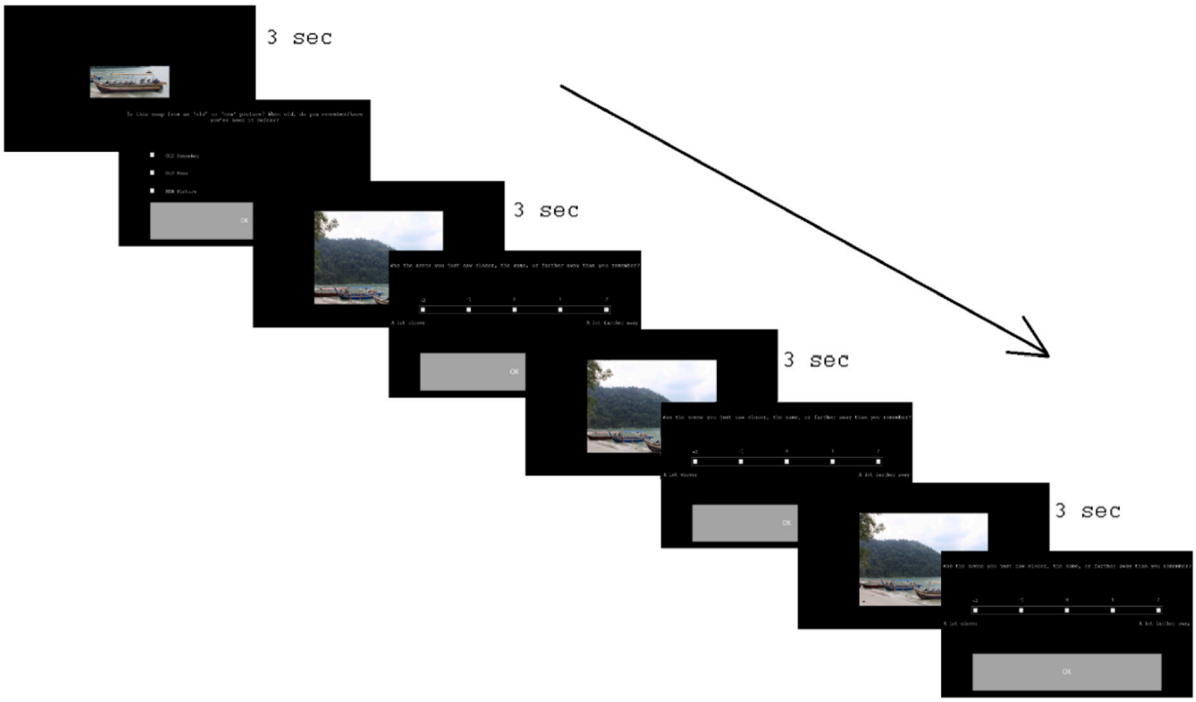

Fig. 1. Example of a trial in the experimental phase.
Note. Participants were first shown a small section of the larger picture, encompassing a central object. Then, participants had to rate whether it was an 'old remember', 'old know' or 'new' picture. Afterwards, they saw 3 views of the full scene and had to indicate on a 5-point Likert scale whether the scene was more close-up, the same or farther away than they remembered. Each picture was shown for 3 s.

indicate whether they met the inclusion criteria and if they did, they could schedule an appointment. Before the start of the experiment, participants signed an informed consent. Participants were compensated with either 1-h study credit or by receiving €6.-. Participants were naïve to the purpose of the study, but were sufficiently debriefed after the experiment had ended.

2.2. Research design and procedure

In the first part of the study, participants looked at 18 pictures of natural scenes on a computer screen (width 31 cm x height 25.5 cm with 1680 × 1050 pixels, respectively). Each picture was shown for 15 s, followed by a 3 s black interval screen. Participants were asked to rate the attractiveness of each scene on a 10-point Likert scale (1 'extremely unattractive' to 10 'extremely attractive'), to make sure they focused on the pictures and to create incidental learning. The experiment used incidental learning in order to prevent conscious control processes that participants might naturally use while learning new information (Macleod, 2008). After viewing the 18 scenes, a 25-min retention period followed. During this period, the experimenter would have the participants do the digit span and block design subtests from the WAIS-IV as filler tasks during this period.

In the experimental test phase that followed after the retention period, participants were again seated behind the computer screen again. Instructions were available on screen before onset of the experiment phase. Participants could request further verbal explanations from the researcher if there were unclarities regarding the instructions. The instructions regarding the task and the distinction between "remember" and "know" can be found in the supplementary materials (Appendix A). They would look at a snapshot (a "snap") of a scene, with 18 snaps taken from 'old' pictures and 18 from distractors which were not-before-used scene images. A snap is a small section of a larger scene, which in most scenes contains the central object of that scene. In scenes in which there was no apparent central object, a different notable focal point within the scene would be used as a snap. Based on this snap, participants had to indicate whether it belonged to an 'old remember', 'old know', or to a 'new' picture. Here, old referred to a previously seen picture and new refers to a picture that participants had not seen before. In short, a "remember" judgment had to be made when anything about the picture itself was recalled. In contrast, a "know" judgment had to be made when the memory of seeing the picture was not accompanied by any contextual or personal details. After the old/new judgment, participants would see 3 versions of the full scene (see Fig. 1). For each set of scenes, one would be 8% more close-up than the original (WC), one would be the same (OR), and one would be 8% more wide-angle than the original (CW). Participants rated the proximity of each picture on a five-point Likert scale (−2 to +2).

2.2.1. Materials

In a pilot phase we first determined the number of stimuli and presentation/delay times. The pilot participants noted that the experimental phase involved complex instructions, which made focussing on the snaps and scenes difficult as time went by. Based on the pilot trials and the performance of the pilot participants, we decided to include a total of 36 scene stimuli, 18 target stimuli and 18 distractors for the experiment. These pictures included natural scenes,[1] such as cities and beaches, with a central focus point (see Fig. 2). Pictures were selected if they presented a natural world scene and comprised of a central object or other apparent focal point. The content of the target stimuli scenes was matched with the content of distractor scenes as much as possible. For example, a stimulus showing a beach would have a distractor of another, comparable beach. All the original target pictures were of the same view-point and came from the experimenter's (LvdB) private archive. All target and distractor stimuli had 3 versions in the test phase

[1] Typically, BE research uses single-item scenes. However, in the current study multi-item natural world scenes were chosen as it was easier to create the snapshot task from these pictures. It should be noted that natural world scenes and single-item scenes do not differ in the amount of BE (Munger & Multhaup, 2016)

Fig. 2. Example of world set scenes used in the experiment.
Note. From left to right: 8% close-up of original – original picture in learning phase – 8% wide-angle of original.

(one WC, one OR, one CW), resulting in 108 pictures that were rated on BE. All versions were manipulated so that they had the same resolution and same size. All pictures were in landscape orientation and were accompanied by a black background. The entire experiment was programmed in OpenSesame (https://osdoc.cogsci.nl/), which allowed the participant to use the mouse to rate the accompanying question (attractiveness, old/new, BE) on screen after each stimulus was shown.

2.2.2. Data-analysis

A within-person design was used to analyse the data. To investigate the efficacy of the remember/know paradigm, using signal detection theory (SDT), *A′* was calculated to indicate discriminative ability, with *B′* representing the response bias.

To investigate whether the boundary extension (BE) effect occurred, there had to be two specific patterns of errors (Intraub & Dickinson, 2008).

1. Identical original pictures: When the learned and test picture were identical (OR), the test picture should be rated as more close-up.
2. Asymmetry in different views: When the learned and test picture are different (WC or CW), a rating asymmetry should occur. A pair of the learned picture and close-up/wide-angle version should be assessed as more similar on CW trials than on WC trials, because the wide-angle view with extended boundaries should approximate the internal representation. Here, CW trials can also show a positive instead of a negative rating.

The third pattern of errors, larger BE in close-up views vs. wide-angle views, was not tested in the experiment since all learned pictures had the same viewpoint in the learning phase.

To investigate whether BE occurred, independent from memory type, a paired *t*-test was used as well as a one-sample t-test. The paired t-test indicated whether there was asymmetry between CW and WC, whereas the one-sample t-test indicated whether OR differed significantly from 0. The significance of the paired *t*-tests was checked using Bonferroni corrected *p*-values. A possible difference between episodic and semantic memory, a 2 × 3 repeated measures ANOVA was used.

The filler tasks resulted in extra collected data, which was not part of the main hypothesis. Additional analyses using this data, can be found in the supplementary materials.

3. Results

3.1. Data inspection

The data for all participants was screened for missing values. It was noted that all data from the experimental phase was missing for 2 participants due to technical difficulties, which lead to the exclusion of their data from the analysis. Additionally, the data showed that 2 cases did not have "know" judgments resulting in missing data. Further inspection revealed that the missing data was due to a problem with registering know responses. In order to obtain a value for the missing know responses, the ranks for remember and know responses were calculated for all participants. By matching a known remember rank with that of a participant who also had a value for the know response, the missing know value could be deducted. Afterwards, the data was checked for outliers by calculating z-scores for all data points. Cases exhibiting z-scores above 2.58, accounting for less than 0.005% of the population, were also checked using a boxplot. When the analysis indicated that the score was an outlier, the case was removed from the analysis (Field, 2013). The entire case was removed when it contained more than one outlier, because of the within-person design. This led to the exclusion of 1 participant who had misinterpreted the instructions, apparent during the debriefing at the end of the experiment, resulting in 33 cases that were used in the analyses. Since $n = 33$, a normal distribution of data was assumed based on the Central Limit Theorem (DasGupta, 2010; Field, 2013). As there was an unplanned disparity in terms of sex distribution, we first analysed Sex effects on BE. No significant differences were present between groups (Appendix B) and therefore further analyses were run without taking into account the sex factor.

3.2. Remember/know paradigm

To determine whether the remember/know paradigm was successful in the current experiment, signal detection theory (SDT) was used, since SDT provides a framework for determining whether the remember/know paradigm distinguishes between two separate memory processes (Dunn, 2004; Hirshman et al., 2002). In addition, SDT interpretation of the remember/know paradigm is consistent with existing data from the remember/know paradigm and has been shown to facilitate theoretical development. The mean and standard error (SE) for both the hits and false alarms can be found in Table 1. The

Table 1
Mean, standard error and sensitivity of remember and know responses.

	Hits		False alarms		Sensitivity	
	M	SE	M	SE	A′	B″
Remember	0.67	0.04	0.05	0.08	0.98	0.84
Know	0.32	0.04	0.16	0.02	0.92	0.12

Note. The table shows the mean proportion of responses for episodic (remember) and semantic (know) memory separately.

sensitivity (A') was calculated as well as the response criterion (B'': see Table 1). Here $A' > 0.5$ indicates good discrimination, with $B'' > 0$ indicating a conservative response bias and $B'' < 0$ indicating a liberal bias (Snodgrass & Corwin, 1988). Since the rate of hits was higher than the false alarms, the non-parametric A' was applied instead of d'. Another reason for using A' is that some participants scored 0 on hits or false alarms and A' is better suited to deal with these scores (Stanislaw & Todorov, 1999). The sensitivity for remember responses ($A' = 0{,}975$, $B'' = 0{,}842$) was higher than that of know responses ($A' = 0{,}915$, $B'' = 0{,}116$), though both showed good discrimination. Therefore, it was concluded that the remember/know paradigm showed good sensitivity in the current BE task.

3.3. Boundary extension

First, the data was analysed to see whether boundary extension (BE) had occurred independent from whether a remember or know judgment was made. Means and SE of the average scores for the close-up (WC), original (OR), and wide-angle (CW) stimuli can be found in Fig. 3. In order to investigate whether BE occurred, the mean scores on OR need to be below 0 to indicate that the same picture at test is rated as closer instead of the same. In addition, WC scores should generate larger ratings (i.e. more negative) than on CW. Finally CW stimuli should yield a mean score closest to 0, independent of its direction.

3.3.1. Assessing the presence of boundary extension

A one-sample *t*-test revealed that the mean score on the OR condition ($M = -0.219$, SD = 0.242) was significantly lower than the 'same' score of 0. This indicates that the OR target was rated as closer up instead of the same. In addition, paired *t*-tests revealed that the WC and CW conditions differed significantly [$t(32) = -12.436$, $p < .001$]. Here, the BE score for WC is significantly larger than for CW, indicating that this pattern for BE has been found. The mean CW score is also closest to 0.

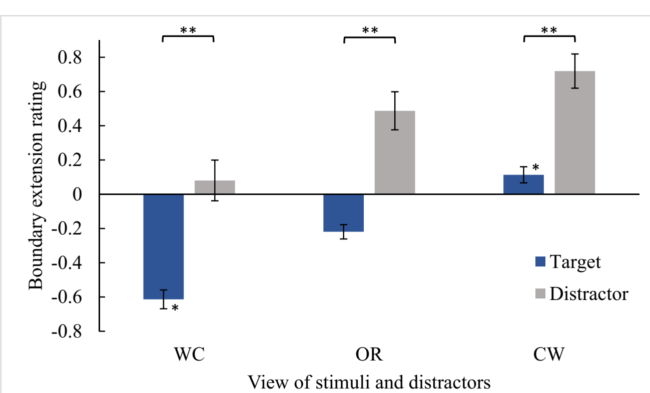

Fig. 3. Mean and standard error of remember and know responses for the target stimuli and distractors for episodic and semantic memory separately.
*Difference is significant at $p < .001$ level.
**Difference is significant at $p < .001$ level.
Note. WC = zoomed in view at test (close-up), OR = original view at test, CW = zoomed out view at test (wide-angle).

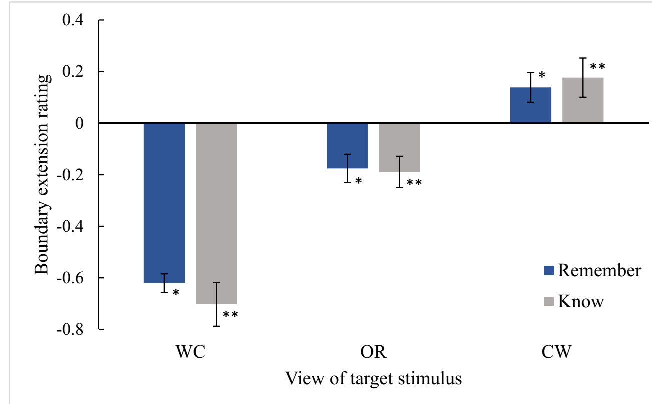

Fig. 4. Means and standard error for each target stimulus view for episodic and semantic memory separately.
*Differences are significant at $p < .001$ level.
**Differences are significant at $p < .001$ level.
Note. Episodic memory is represented by remember judgments, whereas semantic memory is represented by know judgments. WC = zoomed in view at test (close-up), OR = original view at test, CW = zoomed out view at test (wide-angle).

3.3.2. Difference between old and new picture

The scores of the new pictures were also compared with the scores of the old pictures using paired *t*-tests to investigate whether the stimuli produced BE where the distractors should be significantly different from their stimuli counterparts. The paired t-tests revealed that this was indeed the case. Here, $t(31) = -6.037$, $p < .001$ for the WC conditions, $t(31) = -6.211$, $p < .001$ for the OR conditions, and $t(31) = -5.734$, $p < .001$ for the CW conditions. Interestingly, all scores for the distractors were positive ratings (see Fig. 3). The positive ratings for the distractors might indicate that participants might have a natural tendency to detect a scene as more zoomed out in cases where the original information, the snap, is too ambiguous to form a whole internal representation of the scene.

3.3.3. Boundary extension and the remember/know paradigm

In order to investigate BE in episodic and semantic memory separately, an average score for each proximity per memory type was obtained. This resulted in 6 different categories, which can be found with their accompanying mean and SE in Fig. 4.

3.3.3.1. Assessing boundary extension in episodic and semantic memory. Post-hoc paired t-tests showed that BE occurred for each memory type. Two one-sample t-tests were performed in order to investigate whether the OR condition differed from 0. The hypotheses were tested using Bonferroni adjusted alpha levels of 0.025 per test (0.05/2). Both the mean OR score for the remember ($M = -0.176$, $SD = 0.318$, $p = .003$) and know condition ($M = -0.189$, $SD = 0.348$, $p = .004$) were significantly lower than the 'same' score of 0. In addition, the difference between the WC and CW condition from the remember condition was significant [$t(32) = -12.688$, $p < .001$], as was the difference between WC and CW for the know condition [$t(32) = -7.474$, $p < .001$]. These results indicate that BE has occurred for each memory type with the largest rating on WC, a clear distinction between the WC and CW conditions (where the mean of CW is closest to 0) and OR scores that are significantly below 0 (see Fig. 4).

3.3.3.2. Boundary extension in episodic and semantic memory. To test whether there was a difference between memory type and proximity, a 2 × 3 repeated-measures ANOVA was used with the within-subject factors memory (remember, know) and proximity (WC, OR, CW). The factor proximity violated Mauchly's sphericity, $\chi^2 = 14.454$, $p = .001$, so the Greenhouse-Geisser estimate for correcting degrees of freedom was used, ε = 0.729. The results showed a main effect for proximity was found using the Greenhouse-Geisser correction, $F(1.457, 46.625) = 93.076$, $p < .001$, $h^2 = 1.000$. There was, however, no significant difference between the remember and know judgments [$F(1,32) = 0.139$, $p = .712$], neither was the interaction between memory type and proximity [$F(2, 64) = 0.719$, $p = .491$] significant. These results indicates that there is no difference in BE between episodic and semantic memory as measured with the remember/know paradigm.

4. Discussion

The aim of the current study was to determine whether boundary extension (BE) is fully based on episodic memory retrieval or whether it is also controlled by more semantic scheme knowledge. BE is generally thought to occur as a result of an error in the internal representation of a scene (Intraub, 2012). Since this internal layout contains spatio-temporal information, it seemed likely that BE mostly occurs as a result of episodic memory. So far, no study has investigated whether BE also occurs as a result of semantic based retrieval. Therefore, the current study incorporated the remember/know paradigm (Tulving, 1985) into an adaptation of a BE task. Interestingly, this adapted BE task demonstrated that BE occurred in both episodic and semantic memory based responses to the same extent. Two patterns, that are indicative of the presence of BE, were present in both types of memory: the phenomenon that views of scenes identical to the learning phase (OR) were rated negatively, indicating that they were experienced as 'closer' instead of 'the same'. This suggests that the internal representation extrapolated beyond the boundaries of the original picture. The second pattern refers to an asymmetry in the rating for close-up views of learned scenes (WC) and the wide-angle views of learned scenes (CW). The asymmetry indicates that WC would be experienced as much closer, while CW would be closer to 0 indicating that the wide-angle view comes closest to the internal representation.

As expected, the episodic memory condition elicited a BE effect in line with previous studies (Gottesman & Intraub, 2002; Mullally et al., 2012). However, the finding that the semantic memory condition elicited the same strength of BE was quite unexpected. The current findings suggest that the BE effect is not just based on episodic memory retrieval, but possibly also on "semantic guidance", or guidance by the structure and meaning of scenes. Semantic guidance grants access to information from a rich knowledge base, or sets of scene priors, which is accessible from even short views of a scene (Castelhano & Henderson, 2007; Võ & Henderson, 2010). Semantic guidance makes use of diagnostic objects that imply a certain scene category (e.g. a refrigerator implies a kitchen). Most evidence for semantic guidance comes from studies investigating visual search, where participants are required to quickly search for items in a (naturalistic) scene (e.g. Võ & Wolfe, 2012). It is possible that in BE, a process similar to semantic guidance results in an expectation of what lies beyond the boundary of a scene. This expectation, based on semantic knowledge, might suggest that a component of semantic memory retrieval is also able to cause a BE effect similar to the BE effect based on episodic memory retrieval.

As mentioned in the introduction, it is thought that BE also depends on top-down schematic knowledge elicited by a scene (Bainbridge & Baker, 2020; Intraub, 2012). Moreover, there is a general agreement that memory for scenes is at least in part schematic in nature (Intraub, 1997; Irwin, 1991). Schematic knowledge can be activated relatively fast (19 ms: Greene & Olivia, 2009) and provides related global properties related to the scene. In turn, activation of schematic information results in a discrepancy between the actual scene and the internal representation that contains additional global properties (Intraub, 2010). This mechanism might be the underlying cause for the BE effect in cases where the mental representation contains more information than the actual scene (Bainbridge et al., 2019; Intraub, 2012). In light of the current results, it is possible that a more general mechanism, such as schematic knowledge, contains properties that both episodic and semantic modes of memory retrieval utilise when recalling a scene. Semantic guidance as such could help to complete and extend the spatiotemporal context in episodic recollection while it also is used to fill in blanks in the semantic analysis of scenes. A shared general mechanism would be in line with the view proposed by Renoult et al. (2019) that episodic and semantic memory are highly inter-dependent rather than fully dissociable systems. Recollection and familiarity would reflect the contextual and non-contextual extremes of a memory continuum linked together by a shared semantic guidance dimension.

An important control measure was used to establish whether the remember/know paradigm was suitable for use in the present BE task. For the paradigm to be successful, both response types ("remember" and "know") had to show a good sensitivity. The results suggest that sensitivity for both remember and know responses was adequate. This indicates that the paradigm was successful in discriminating between remember and know. Moreover, sensitivity is generally lower for "know" responses, because familiarity-based recognition involves lower memory-strength (Anderson & Bower, 1972). Memory-strength refers to the amount of source memory that is being retrieved for a test item. Source memory is the spatiotemporal aspect of recollection (important for episodic memory), which can be triggered by contextual information (Pandey, 2011). In other words, when more source information is available, there will be more recollection (remember) responses (Slotnick & Dodson, 2005). This pattern was also present in the current study. Moreover, participants also had a conservative response bias for both remember and know responses. These response biases indicate that participants applied a high response criterion, meaning that they had high levels of certainty before choosing remember or know.

The current study had its share of strengths and limitations. For instance, for future research it would be advisable to correct the proportion of know responses, since evidence suggests that analysing the uncorrected know responses leads to an underestimation of familiarity (Yonelinas, 2002). Furthermore, to investigate whether BE occurred in individual trials, it was not possible to create a receiver operating characteristic (ROC) curve (see e.g.: Migo et al., 2012). Here, an estimation of overall performance across the BE task would not have been indicative either, since the effect would cancel out. However, evidence does suggest that certain ROC patterns are indicative of either a dual-process model or remember/know responses or of a single-process model (Morris & Rugg, 2004). It would also be advisable to add an independent memory task as it would allow to investigate whether participants with stronger episodic memory would experience more BE, especially considering the fact that participants in the current study were all university students where good episodic memory could be expected. On the other hand, the current design made it possible to study the difference between episodic and semantic memory by only presenting a scene once before participants made their remember/know response. The way in which the snaps were designed made it possible to create a situation of cued recall without providing explicit cues/information about the boundaries of the scene. Moreover, we observed that showing all versions of the complete scene (WC, OR, CW) in succession, separated by the rating scale, did not change the strength of the BE effect.

5. Conclusion

The aim of the current study was to investigate whether boundary extension (BE) is an exclusive product of episodic memory or whether semantic scene knowledge is also involved. No other study, to our knowledge, has directly investigated this distinction with regard to the BE effect. Based on the findings from the current study, it appears that BE is not necessarily fully based on episodic memory retrieval. BE also involves a form of semantic based memory retrieval, where semantic scheme knowledge appears to be involved. This might suggest that BE is part of more general declarative memory, instead of solely a consequence of or prerequisite for recollection. In other words, BE might not be a phenomenon uniquely connected to episodic memory, but it may also arise from other forms of declarative memory. Additionally, the fact that BE was not larger in episodic memory suggests that the feeling of recollection does not fully depend on the ability to imagine the spatial frames of scenes. It seems that an automatic semantic process, driven by schematic spatial knowledge, is also implicated in the occurrence of BE. Future research should closer investigate this semantic mechanism amongst other by comparing BE across remember and know responses in highly familiar scenes to completely novel scenes (where semantic guidance might be lower). Gaining more insight in the BE phenomenon could provide more knowledge about processes implicated in episodic and semantic based memory retrieval, but also in the way in which our brain makes predictions about the external world.

CRediT authorship contribution statement

Lisa van den Bos: Conceptualisation, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – Orignal draft and Review & Editing, Visualisation.

Jeroen Benjamins: Validation, Writing – Review & Editing.

Albert Postma: Conceptualisation, Methodology, Validation, Writing – Review & Editing, Supervision, Project administration, Funding acquisition.

Declaration of competing interest

None.

Acknowledgements

None.

Funding

This research did not receive any specific grant from funding agencies in public, commercial, or not-for-profit sectors.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.actpsy.2020.103190.

References

Anderson, J. R., & Bower, G. H. (1972). Recognition and retrieval processes in free recall. *Psychological Review, 79*, 97–123.
Bainbridge, W. A., & Baker, C. I. (2020). Boundaries extend and contract in scene memory depending on image properties. *Current Biology, 30*, 1–7. https://doi.org/10.1016/j.cub.2019.12.004.
Bainbridge, W. A., Hall, E. H., & Baker, C. I. (2019). Drawings of real-world scenes during free recall reveal detailed object and spatial information in memory. *Nature Communications, 10*(5), 1–13. https://doi.org/10.1038/s41467-018-07830-6.
Candel, I., Merckelbach, H., Houben, K., & Vandyck, I. (2004). How children remember neutral and emotional pictures: Boundary extension in children's scene memories. *American Journal of Psychology, 117*(2), 249–257.
Castelhano, M. S., Fernandes, S., & Theriault, J. (2018). Examining the hierarchical nature of scene representations in memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 45*(9), 1619–1633. https://doi.org/10.1037/xlm0000660.
Castelhano, M. S., & Henderson, J. M. (2007). Initial scene representations facilitate eye movement guidance in visual search. *Journal of Experimental Psychology: Human Perception and Performance, 33*(4), 753–763. https://doi.org/10.1037/0096-1523.33.4.753.
DasGupta, A. (2010). In G. Casella, S. Fienberg, & I. Olkin (Eds.). *Fundamentals of probability: A first course*. New York, New York: Springer Texts in Statistics.
Dunn, J. C. (2004). Remember-know: A matter of confidence. *Psychological Review, 111*(2), 524–542. https://doi.org/10.1037/0033-295X.1112.524.
Dunn, J. C. (2008). The dimensionality of the remember-know task: A state-trace analysis. *Psychological Review, 115*, 426–446. https://doi.org/10.1037/0033-295X.115.2.426.
Evans, G. W. (1980). Environmental cognition. *Psychological Bulletin, 88*, 259–287.
Field, A. (2013). *Discovering statistics using IBM SPSS statistics: And sex and drugs and rock "n" roll* (4th edition). London, England: Sage Publications Ltd.
Friston, K. (2010). The free-energy principle: A unified brain theory? *Nature Reviews Neuroscience, 11*(2), 127–138.
Frithsen, A., Stark, S. M., & Stark, C. E. L. (2019). Response bias, recollection, and familiarity in individuals with highly superior autobiographical memory (HSAM). *Memory, 27*(6), 739–749. https://doi.org/10.1080/09658211.2018.1561896.
Gardiner, J. M. (2001). Episodic memory and autonoetic consciousness: A first-person approach. *Philosophical Transactions of the Royal Society of Londen B, 356*, 1351–1361. https://doi.org/10.1098/rstb.2001.0955.
Gardiner, J. M., & Java, R. I. (1991). Forgetting in recognition memory with and without recollective experience. *Memory and Cognition, 19*, 617–623.
Gardiner, J. M., & Java, R. I. (1993). Recognition memory and awareness: An experiential approach. *European Journal of Cognitive Psychology, 5*(3), 337–346.
Gottesman, C. V., & Intraub, H. (2002). Surface construal and the mental representation of scenes. *Journal of Experimental Psychology: Human Perception and Performance, 28*, 589–599.
Greene, M. R., & Olivia, A. (2009). The briefest of glances: The time course of natural scene understanding. *Cognitive Psychology, 58*, 137–176 doi: S0010-0285(08)00045-5.
Hamilton, M., & Rajaram, S. (2003). States of awareness across multiple memory tasks: Obtaining a "pure" measure of conscious recollection. *Acta Psychologica, 112*, 43–69.
Hirshman, E., Lanning, K., Master, S., & Henzler, A. (2002). Signal-detection models as tools for interpreting judgments of recollections. *Applied Cognitive Psychology, 16*, 151–156. https://doi.org/10.1002/acp.758.
Intraub, H. (1997). The representation of visual scenes. *Trends in Cognitive Science, 1*, 217–221 doi: S1364-6613(97)01067-X.
Intraub, H. (2010). Rethinking visual scene perception: A multisource model. In B. H. Ross (Ed.). *The psychology of learning and motivation* (pp. 231–264). . https://doi.org/10.1016/S0079-7421(10)52006-1.
Intraub, H. (2012). Rethinking visual scene perception. *Wiley Interdisciplinary Reviews: Cognitive Science, 3*, 117–127.
Intraub, H., & Dickinson, C. (2008). False memory 1/20th of a second later: What the early onset of boundary extension reveals about perception. *Psychological Science, 19*, 1007–1014.
Intraub, H., Gottesman, C. V., & Bills, A. J. (1998). Effects of perceiving and imagining scenes on memory for pictures. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 24*(1), 186–201.
Intraub, H., & Richardson, M. (1989). Wide-angle memories of close-up scenes. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15*, 179–187.
Irwin, D. E. (1991). Information integration across saccadic eye movements. *Cognitive Psychology, 23*, 420–456 Doi: 0010-0285(91)90015-G.
Knowlton, B. J., & Squire, L. R. (1995). Remembering and knowing: Two different expressions of declarative memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21*, 699–710.
Lutz, N. D., Diekelmann, S., Hinse-Stern, P., Born, J., & Rauss, K. (2017). Sleep supports the slow abstraction of gist from visual perceptual memories. *Scientific Reports, 7*, 1–9. https://doi.org/10.1038/srep42950.
Macleod, C. M. (2008). Implicit memory tests: Techniques for reducing conscious intrusion. In J. Dunlosky, & R. A. Bjork (Eds.). *Handbook of metamemory and memory* (pp. 245–263). New York, NY, USA: Psychology Press.
McDermott, K. B. (2006). Paradoxical effects of testing: Repeated retrieval attempts enhance the likelihood of later accurate and false recall. *Memory and Cognition, 34*, 261–267.
Mickes, L., Seale-Carlisle, T. M., & Wixted, J. T. (2013). Rethinking familiarity: Remember/know judgments in free recall. *Journal of Memory and Language, 68*(4), 333–349. https://doi.org/10.1016/j.jml.2013.01.001.
Migo, E. M., Mayes, A. R., & Montaldi, D. (2012). Measuring recollection and familiarity: Improving the remember/know procedure. *Consciousness and Cognition, 21*, 1435–1455. https://doi.org/10.1016/j.concog.2012.04.014.
Morris, R. G. M., & Rugg, M. D. (2004). Messing about in memory. *Nature Neuroscience, 7*, 1171–1173. https://doi.org/10.1038/nn1104-1171.
Mullally, S. L., Intraub, H., & Maguire, E. A. (2012). Attenuated boundary extsension produces a paradoxical memory advantage in amnestic patients. *Current Biology, 22*, 261–268. https://doi.org/10.1016/j.cub.2012.01.001.
Munger, M. P., & Multhaup, K. S. (2016). No imagination effect on boundary extension. *Memory and Cognition, 44*, 73–88. https://doi.org/10.3758/s13421-015-0541-3.
Pandey, J. (2011). Source memory. In J. S. Kreutzer, J. DeLuca, & B. Caplan (Eds.). *Encyclopedia of clinical neuropsychology*. USA, New York, NY: Springer.
Park, S., Intraub, H., Yi, D. J., Widders, D., & Chun, M. M. (2007). Beyond the edges of a view: Boundary extension in human scene selective visual cortex. *Neuron, 54*, 335–342.
Renoult, L., Irish, M., Moscovitch, M., & Rugg, M. D. (2019). From knowing to remembering: The semantic-episodic distinction. *Trends in Cognitive Sciences, 23*(12), 1041–1057. https://doi.org/10.1016/j.tics.2019.09.008.
Schwedes, C., Scherer, D., & Wentura, D. (2019). Manipulating the depth of processing reveals the relevance of second eye fixations for recollection but not familiarity. *Psychological Research Psychologische Forschung*. https://doi.org/10.1007/s00426-019-01218-x.
Seamon, J. G., Schlegel, S. E., Hiester, P. M., Landau, S. M., & Blumenthal, B. F. (2002). Misremembering pictured objects: People of all ages demonstrate the boundary extension illusion. *American Journal of Psychology, 115*(2), 151–167.
Slotnick, S. D., & Dodson, C. S. (2005). Support for a continuous (single-process) model of recognition memory and source memory. *Memory & Cognition, 33*, 151–170.
Snodgrass, J. G., & Corwin, J. (1988). Pragmatics of measuring recognition memory:

Applications to dementia and amnesia. *Journal of Experimental Psychology, 117*(1), 34–50.
Spencer, C., Blades, M., & Morsley, K. (1989). *The child in the physical environment: The development of spatial knowledge and cognition.* Hoboken, New Jersey: Wiley and Sons.
Stanislaw, H., & Todorov, N. (1999). Calculation of signal detection measures. *Behavior Research Methods, Instruments, & Computers, 31*(1), 137–149.
Tulving, E. (1985). Memory and consciousness. *Canadian Psychology, 26*, 1–12.
Tulving, E. (1993). What is episodic memory? *Current Perspectives in Psychological Science, 2*, 67–70.
Võ, M. L.-H., & Henderson, J. M. (2010). The time course of initial scene processing for eye movement guidance in natural scene search. *Journal of Vision, 10*(14), 1–13. https://doi.org/10.1167/10.3.14.
Võ, M. L.-H., & Wolfe, J. M. (2012). The interplay of episodic and semantic memory in guiding repeated search in scenes. *Cognition, 126*, 198–212. https://doi.org/10.1016/j.cognition.2012.09.017.
Wang, W. C., & Yonelinas, A. P. (2012a). Familiarity is related to conceptual implicit memory: An examination of individual differences. *Psychonomic Bulletin & Review, 19*, 1154–1164. https://doi.org/10.3758/s13423-012-0298-7.
Wang, W. C., & Yonelinas, A. P. (2012b). Familiarity and conceptual implicit memory: Individual differences and neural correlates. *Cognitive Neuroscience, 3*(3–4), 213–214. https://doi.org/10.1080/17588928.2012.689968.
Wixted, J. T. (2007). Dual-process theory and signal-detection theory of recognition memory. *Psychological Review, 114*(1), 152–176. https://doi.org/10.1037/0033-295X.114.1.152.
Wixted, J. T., & Mickes, L. (2010). A continuous dual-process model of remember/know judgments. *Psychological Review, 117*(4), 1025–1054.
Yee, E., Chrysikou, E. G., & Thompson-Schill, S. L. (2013). Semantic memory. In K. Ochsner, & S. Kosslyn (Vol. Eds.), *The Oxford handbook of cognitive neuroscience. Vol. 1: Core Topics*. *The Oxford handbook of cognitive neuroscience* (pp. 353–374). Oxford University Press.
Yee, E., Jones, M. N., & McRae, K. (2017). Semantic memory. In J. T. Wixted, & S. Thompson-Schill (Eds.). *The Stevens' handbook of experimental psychology and cognitive neuroscience (4th edition, volume 3: Language and thought)*New York, NY: Wiley. https://doi.org/10.1037/0278-7393.24.1.186.
Yonelinas, A. P. (2002). The nature of recollection and familiarity: A review of 30 years of research. *Journal of Memory and Language, 46*, 441–517.
Yonelinas, A. P., & Parks, C. M (2007). Receiver operating characteristics (ROCs) in recognition memory: A review. *Psychological Bulletin, 133*(5), 800–832. https://doi.org/10.1037/0033-2909.133.5.800.