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Short Communication

Familiarity from the configuration of objects in 3-dimensional space and its relation to déjà vu: A virtual reality investigation

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ABSTRACT

Déjà vu is the striking sense that the present situation feels familiar, alongside the realization that it has to be new. According to the Gestalt familiarity hypothesis, déjà vu results when the configuration of elements within a scene maps onto a configuration previously seen, but the previous scene fails to come to mind. We examined this using virtual reality (VR) technology. When a new immersive VR scene resembled a previously-viewed scene in its configuration but people failed to recall the previously-viewed scene, familiarity ratings and reports of déjà vu were indeed higher than for completely novel scenes. People also exhibited the contrasting sense of newness and of familiarity that is characteristic of déjà vu. Familiarity ratings and déjà vu reports among scenes recognized as new increased with increasing feature-match of a scene to one stored in memory, suggesting that feature-matching can produce familiarity and déjà vu when recall fails.

1. Introduction

Déjà vu is a particularly jarring recognition illusion, where an ostensibly new situation feels as if it has been experienced before (Brown, 2003). Though many theories of déjà vu exist (Brown & Marsh, 2010), the present study focuses on the Gestalt familiarity hypothesis (Brown, 2004; Brown & Marsh, 2010; Dashiell, 1937), according to which déjà vu is elicited by familiarity with the arrangement of the elements within a scene. For example, when visiting a friend's home for the first time, one may have a strange sense of having been in that living room before. Perhaps the arrangement of the furniture in the new friend's living room (e.g., the way that the couches, tables and lamps are arranged) maps onto an arrangement that was seen before, perhaps in the person's doctor's office waiting area. The inability to recall the doctor's office waiting area as the source of this familiarity leads to the experience of déjà vu. We examined this idea in the present study using virtual reality (VR) technology.

That déjà vu may be related to familiarity is not a new idea in memory research, and has been suggested by many (e.g., Brown & Marsh, 2010; Cleary, 2008; Cleary, Ryals, & Nomi, 2009; Jacoby & Whitehouse, 1989; Roediger, 1996). However, the idea that familiarity can be elicited by the configuration of elements is new and theoretically important. Familiarity is thought to emerge from a match between the features present in a current situation and features stored in memory (e.g., Clark & Gronlund, 1996; Jones, Brown, & Atchley, 2007), but the nature of those features is not well-understood. Though

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some research has begun to identify the types of features that can produce familiarity in the absence of recall (e.g., Cleary, 2004; Cleary, Langley, & Seiler, 2004; Cleary, Winfield, & Kostic, 2007; Kostic & Cleary, 2009), no studies have examined whether the 3D arrangement of elements can produce familiarity with a novel scene in the absence of recall. Furthermore, though many studies that have manipulated familiarity have related it to déjà vu (e.g., Brown & Marsh, 2008, 2009, 2010; Cleary et al., 2009; Jacoby & Whitehouse, 1989), no studies have yet created the simultaneous recognition of newness alongside the sense of familiarity that defines the déjà vu experience. We attempted to create this simultaneous sense of familiarity and newness in the present study.

Because recognition memory can be based on either recollection or familiarity (Diana, Reder, Arndt, & Park, 2006; Mandler, 2008; Yonelinas, 2002), it is important to separate familiarity-based from recollection-based recognition in order to identify the types of features that can produce familiarity. We did so in the present study, using the recognition without cued recall (RWCR) method (Cleary, 2004), which is ideally-suited for examining familiarity in the absence of recall. In this method, participants first study a list of items (e.g., OBSTRUCTION, HEMLOCK) and are then presented with a test list containing cues, half of which resemble studied items (e.g., OBSTETRICIAN, HAMMOCK). For each test cue, participants attempt to recall a word from study that resembles it. Even when they cannot, they are asked to judge the familiarity of the test cue itself. When recall fails, RWCR occurs when familiarity ratings are higher for cues that do resemble studied items compared to those that do not resemble studied words. This method is ideally-suited for probing the features that produce familiarity because cues can be designed to resemble studied items on one selected feature; if RWCR occurs, it suggests that familiarity can be elicited by that particular type of feature.

In the present study, we implemented a scene version of the RWCR method used by Cleary et al. (2009). They did not disentangle element from configural familiarity, nor did they produce the simultaneous sense of newness and familiarity characteristic of déjà vu, but they did show that a test scene's resemblance to a studied scene increased both familiarity and reports of déjà vu in the absence of recall. We enhanced the experiential richness and verisimilitude of the display by using color 3D scenes (Cleary et al., 2009, used 2D black-and-white scenes). Using a 3D head-mounted display (HMD) with head-tracking (Fig. 1A) enabled a feeling of being immersed inside a 3-dimensional scene, complete with stereographic depth cues and the ability to look around (by turning one's head) as if physically present. To manipulate scene configuration, we placed elements in specific locations on a grid to achieve a precise duplication of element position configuration from study to test without duplicating the elements themselves. Thus, each scene had a configurally similar counterpart (Fig. 1B), or a novel scene whose elements mapped onto the locations of the elements within the first scene (Fig. 2). We were particularly interested in those situations where recall of the earlier scene failed: would novel scenes that mapped onto studied scenes in their configuration be treated as more familiar than novel scenes that did not? If so, this would support the idea that the arrangement of elements, by itself, can produce familiarity.

Our first priority was to replicate the familiarity findings of Cleary et al. (2009) with our 3D configural resemblance manipulation in a VR setting; this was achieved in Experiment 1. Our next priority was to demonstrate the simultaneous sense of familiarity and newness that characterizes the déjà vu experience. Specifically, can configural resemblance increase familiarity and reports of déjà vu when participants recognize that a current situation is new and never been experienced before? This essential characteristic of déjà vu (Brown, 2004) has never before been demonstrated in a laboratory study.

2. Experiment 1

2.1. Method

2.1.1. Participants

Twenty-four Colorado State University students participated for course credit.

2.1.2. Equipment

The VR system included an eMagin z800 Visor with head-tracking (Fig. 1A). A quad core CPU with an NVIDIA G-force 9800 video card and running Windows XP utilized a modified version of iZ3D's 3D monitor driver. Plausible indoor and outdoor environments were generated with The Sims 2 game engine, resulting in an immersive stereographic 3D environment that could be explored through head or body movements.

2.1.3. Stimuli

Sixty-four primary scenes were created. For each, a configurally similar scene was also created (Figs. 1B, 2B and C). The 3D virtual rooms, scenes and landscapes were built on a grid (Fig. 2A) on which were placed walls, floors, ceilings, architectural features, landscape terrains and elements (e.g., chairs, plants, light fixtures, artwork). The grid allowed a precise match between primary (Fig. 2B) and configurally similar (Fig. 2C) scenes' element positions.

2.1.4. Procedure

Participants received two study-test blocks, each containing a 16-scene study list followed by a 32-scene test list (similar to Cleary (2004) and Cleary et al. (2009)). No test scene had appeared at study; half resembled a studied scene in element configuration and half did not. Counterbalancing assured that each test scene corresponded to studied vs. non-studied scenes

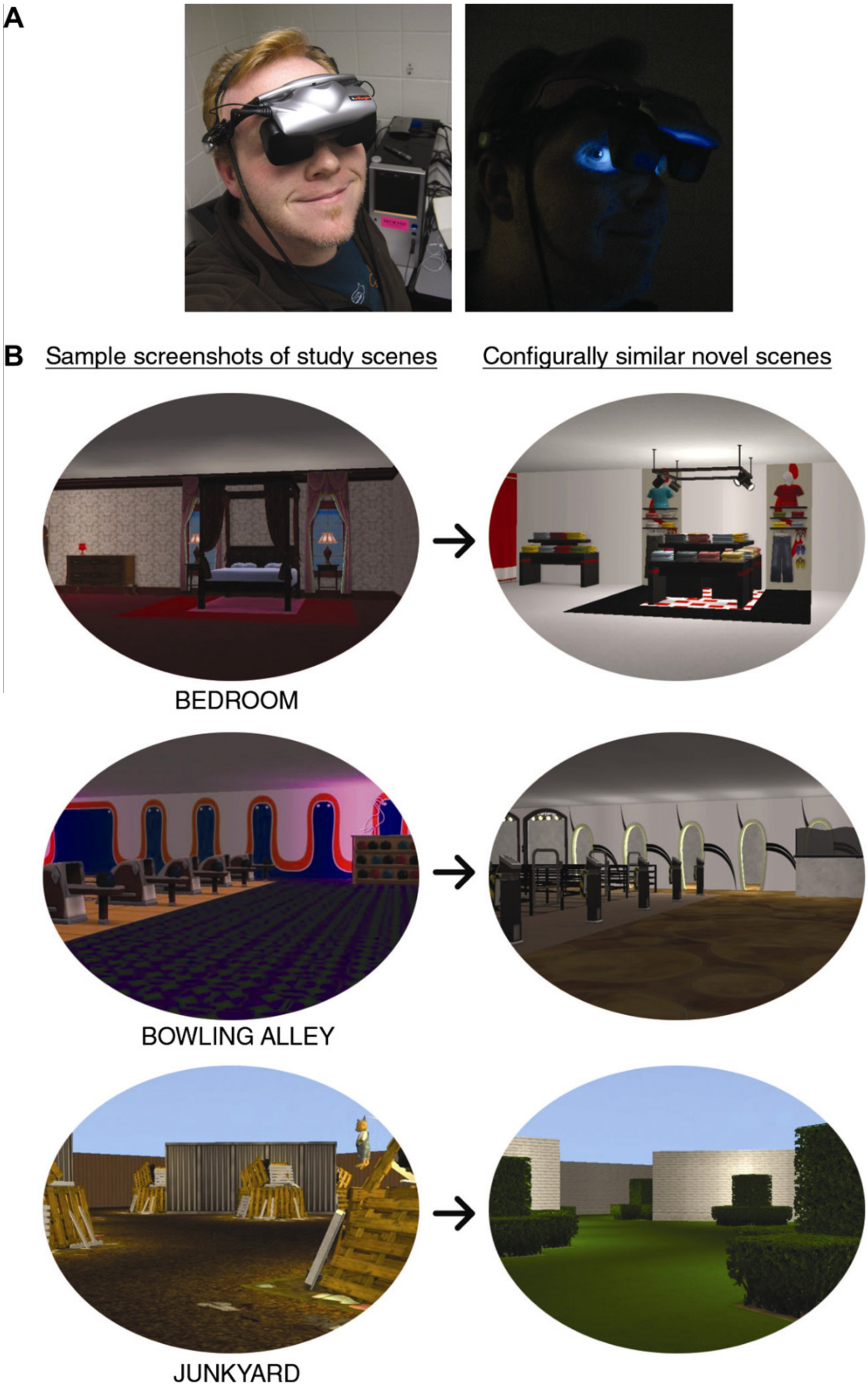

Fig. 1. (A) The eMagin z800 3D head-mounted display (HMD); head-tracking enables immersive viewing of each scene through the turning of one's head to look around and 3D presentation allows for depth perception. (B) Sample 2D screenshots of configurally similar scenes (study on left; test on right). Though screenshots are 2D, the actual scenes were presented in stereographic 3D through the HMD shown in A; each illustration represents only a portion of the entire scene, as each could be viewed immersively by turning one's head or body to look left, right, up or down.

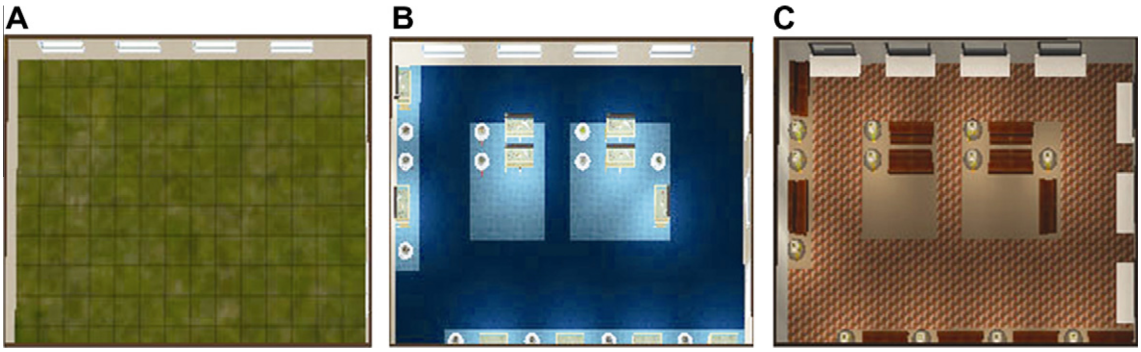

Fig. 2. (A) The grid used for item placement in scene construction; (B) sample study scene (AQUARIUM) with elements (fish tanks; floor tiles). (C) Sample corresponding test scene (a doctor's office reception area) configurally resembling the study scene (aquarium): couches replace aquariums, carpet replaces floor tiles, reception windows with countertops replace underwater aquarium views along the wall, and lamp tables replace fish bowl stands.

equally often across participants. After fitting the equipment, the laboratory lights were turned off and the participant's viewing point was set within the first scene. Participants were then free to turn their heads (left, right, up, down) or swivel in their chairs to achieve different views of the same scene, but could not navigate (e.g., move forward) through the scene. Participants were advanced through additional scenes by shortcut-keys, and began each at a fixed point. As participants viewed each study scene, the experimenter spoke the scene's label (e.g., bedroom) and the participant repeated it aloud. Scene nameability accuracy was verified at 99% with 10 pilot participants (cf. Cleary et al., 2009).

Participants viewed each study scene for 10 s, after which they advanced to the next. After the 16 study scenes, the test series was initiated. Instructions emphasized that all test scenes were novel (not seen previously), but that some might resemble the layout of earlier-viewed scenes. For each test scene, participants were asked to (1) rate its familiarity from 0 (extremely unfamiliar) to 10 (extremely familiar), (2) recall the name of any earlier scene resembling it, and (3) indicate if they were experiencing déjà vu (yes/no). Probing déjà vu trial-by-trial is an established method for investigating relatively rare cognitive states, such as tip-of-the-tongue (Brown, 2011). Similar to research on tip-of-the-tongue states (Schwartz, 2002), participants were given an explicit definition of déjà vu – a feeling of having been somewhere or done something before, despite knowing that the current situation is new. As with the study scenes, participants began viewing from a fixed point in each test scene, but were free to look around for as long as they wished. During each test trial, the experimenter prompted participants for three oral decisions in a consistent order (see above) and recorded their responses.

2.2. Results

Participants recalled an average of 41% (SD = 15%) of the studied scenes in response to their configurally similar counterparts at test, leaving an average of 59% unrecalled. Following from prior studies (Cleary, 2004; Cleary et al., 2009), we examined test scenes where participants failed to recall the similar study scene. Familiarity ratings were significantly higher for test scenes resembling ($M = 3.23$, $SD = 1.13$) than not resembling ($M = 2.27$, $SD = 1.02$) study scenes, $t(23) = 5.04$, $SE = .19$, $d = 1.05$, $p < .001$, and déjà vu was significantly more likely for scenes resembling ($M = .27$, $SD = .19$) than not resembling ($M = .17$, $SD = .15$) study scenes, $t(23) = 3.87$, $SE = .03$, $d = .78$, $p = .001$; both probabilities were significantly different from zero (respectively): $ts(23) = 7.04$ and 5.61, $ps < .001$. These effects were also found in item analyses, and there was a significant positive correlation (by item) between the familiarity enhancement and the déjà vu increase (from resembling versus not resembling a studied scene), $r(24) = .70$, $p < .001$. The same effects were also found excluding misidentifications, considering only those trials with no attempt at recall.

3. Experiment 2

Experiment 2 altered the design from Experiment 1 to include actually-studied scenes (old) at test, in addition to new scenes configurally resembling studied scenes (similar but new) and new scenes not resembling studied scenes (completely new). The purpose of this was to determine whether the increased familiarity and déjà vu from configural resemblance of new-to-old scenes would also be found in a test context where some of the scenes were actually old.

3.1. Method

3.1.1. Participants

Eighteen Colorado State University students participated in exchange for payment.

3.1.2. Stimuli

Stimuli were selected from among those used in Experiment 1.

A Mean Scene Recognition Rates (Old-new Discrimination)

	Scenes Called Old	Scenes Called New
Old/Studied Scenes	.80	.19
New Scenes Configurally Similar to Studied Scenes	.08	.92
New Scenes Dissimilar to Studied Scenes	.04	.96

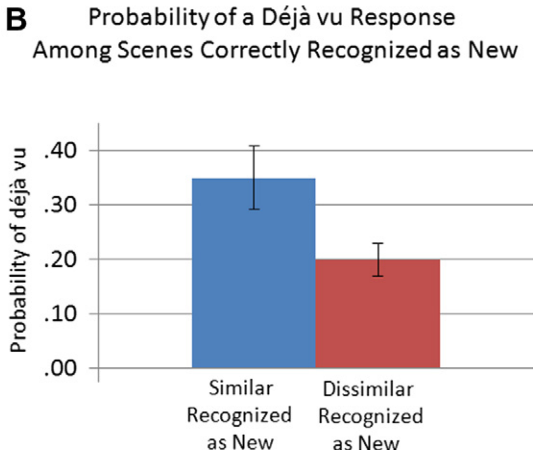

Fig. 3. (A) Scene recognition rates (Experiment 2). (B) Probability of a déjà vu response in the three categories for which all 18 participants gave responses (Experiment 2).

3.1.3. Procedure

The procedure was the same as in Experiment 1, except that the experimenter no longer named each test scene for the participant (as this would not be relevant at test) and the test procedure was changed in the following ways. First, each of the two test phases consisted of 24 scenes: 8 presented at study, 8 new and configurally similar to studied scenes, and 8 new and configurally unrelated to any studied scene. Scenes were counterbalanced across condition, such that each scene (or version of a scene) appeared equally often in each condition (studied, similar-but-new, and non-similar-new) across participants. At test, participants provided three responses for each test scene: (1) familiarity rating (0–10, as in Experiment 1), (2) an old/new (studied/not studied) recognition judgment, and (3) déjà vu (yes/no).

3.2. Results

Participants were generally able to recognize new test scenes that resembled studied scenes as new (Fig. 3A). Participants rarely falsely recognized new scenes as old, and eight had no such errors. Two participants indicated déjà vu for 100% of the old scenes that were called old, suggesting that they may have followed a strategy of reporting déjà vu every time a scene was familiar. However, most followed our definition of déjà vu.[1] Because we defined déjà vu as a simultaneous recognition of newness alongside a feeling of familiarity, our primary interest was in test scenes identified as "new."[2] Among these, scenes configurally similar to earlier-viewed scenes indeed elicited a greater proportion of déjà vu responses than scenes dissimilar to earlier-viewed scenes (Fig. 3B), $t(17) = 3.39$, $SE = .04$, $d = .82$, $p < .01$. This pattern held even after excluding the two participants who had indicated déjà vu for all old-called-old scenes, with scenes configurally similar to earlier-viewed scenes eliciting a greater proportion of déjà vu responses ($M = .34$, $SD = .26$) than scenes dissimilar to earlier-viewed scenes ($M = .19$, $SD = .13$), $t(15) = 3.02$, $SE = .05$, $d = .78$, $p < .01$.

Also of interest are old scenes incorrectly identified as new (Fig. 4A); 15 participants had such errors. Among these 15 participants, 77% of old scenes were recognized as old (24% of which elicited déjà vu reports), leaving 23% that were incorrectly labeled new (58% of which elicited déjà vu reports); 91% of the similar scenes were recognized as new (35% of which elicited déjà vu reports) and 95% of the non-similar scenes were recognized as new (19% of which elicited déjà vu reports). Old scenes incorrectly identified as new elicited more déjà vu responses than similar scenes correctly recognized as new, $t(14) = 2.82$, $SE = .08$, $d = .75$, $p < .05$, which in turn elicited more déjà vu responses than dissimilar scenes recognized as new, $t(14) = 3.18$, $SE = .05$, $d = .85$, $p < .01$. This pattern held in items analyses, as well. Even among the 13 participants who remained after excluding the two who indicated déjà vu for all old-called-old items, the same overall pattern occurred: Old scenes incorrectly identified as new elicited more déjà vu responses ($M = .51$, $SD = .39$) than similar scenes recognized as

[1] The percentages of old-called-old items eliciting déjà vu among the remaining (16) participants were 0% (8), 6% (1), 7% (1), 8% (2), 11% (1), 29% (1), 33% (1), and 67% (1).

[2] If familiarity can indeed be accompanied by a simultaneous sense of newness, as we suggest in our definition of déjà vu, then it is not clear how a simultaneous sense of newness, if also a continuous variable, would affect the tendency to call something old as opposed to calling it new on a recognition test. If these are continuous dimensions, then we would expect some items that elicit a simultaneous sense of familiarity and newness to fall into the "old" category, just as some new items sometimes fall into the "old" category on recognition tests due to seeming familiar or resembling studied items (e.g., Cleary, Morris, & Langley, 2007). That is, if familiarity alone can sometimes drive subjects to call an item "old" on a recognition test, then it is also very likely that items that elicit a simultaneous sense of familiarity and newness will sometimes fall into the old category (because of the familiarity component). This may explain why many subjects sometimes reported experiencing déjà vu for old scenes that were called old on the recognition test. Nevertheless, our primary interest was in scenes deemed new so that we could examine both the reported familiarity levels and the reports of déjà vu among scenes that clearly elicited a sense of newness.

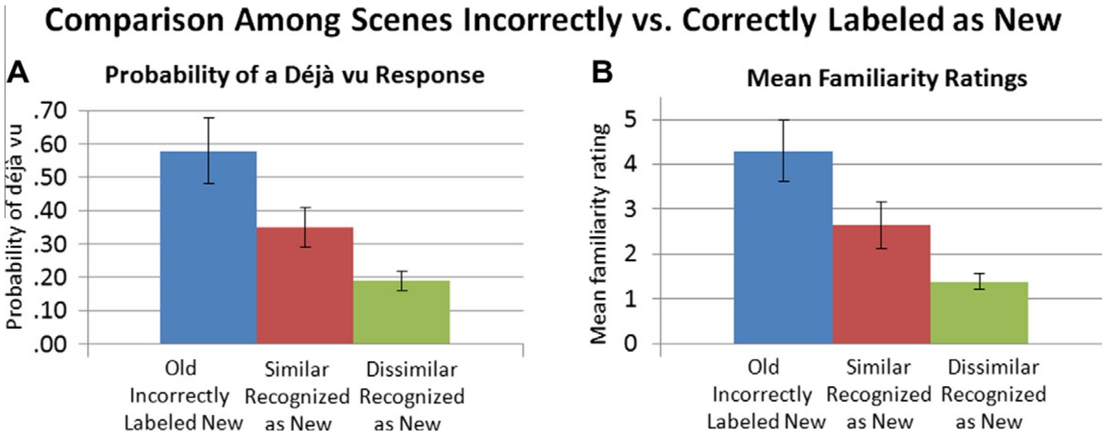

Fig. 4. Déjà vu rates and familiarity ratings for scenes called new (Experiment 2).

new ($M = .33$, $SD = .26$), $t(12) = 2.12$, $SE = .09$, $d = .61$, $p = .056$, which in turn elicited more déjà vu responses than the dissimilar scenes recognized as new ($M = .18$, $SD = .13$), $t(12) = 2.76$, $SE = .06$, $d = .80$, $p < .05$. Overall, 73% of participants (11 of 15) showed a higher probability of déjà vu to old-called-new than to similar-called-new items (and 69%, or nine out of 13, of those remaining after excluding the two participants indicating déjà vu for all old-called-old scenes). This outcome strengthens support for configural resemblance contributing to déjà vu because a scene must logically be configurally closer to itself than to a new scene that is only similar to it; it also supports a feature-matching approach to familiarity and déjà vu. The increased familiarity elicited by an increased match to an experience stored in memory (Clark & Gronlund, 1996) appears to have contributed to this pattern of déjà vu rates, as familiarity ratings mirrored déjà vu rates (Fig. 4B). Familiarity ratings were higher when people identified an old scene as new than a configurally similar scene as new, $t(14) = 2.78$, $SE = .60$, $d = .74$, $p < .05$, and when people called a configurally similar scene new than a dissimilar scene new, $t(14) = 2.81$, $SE = .44$, $d = .75$, $p < .05$. This pattern held in items analyses, as well. Even among the 13 participants who remained after excluding the two who indicated déjà vu for all old-called-old scenes, the same overall pattern occurred: Familiarity ratings were higher for old scenes called new ($M = 4.02$, $SD = 2.67$) than for similar scenes called new ($M = 2.50$, $SD = 2.14$), $t(12) = 2.28$, $SE = .67$, $d = .66$, $p < .05$, which in turn elicited higher familiarity ratings than dissimilar scenes recognized as new ($M = 1.39$, $SD = 0.71$), $t(12) = 2.25$, $SE = .49$, $d = .65$, $p < .05$.

4. Discussion

Experiment 1 confirmed that the spatial configuration of elements within a scene can produce familiarity in the absence of recall in an immersive 3D VR environment. This finding adds to a growing literature aimed at systematically identifying the types of features that elicit a sense of familiarity (e.g., Cleary, 2004; Cleary et al., 2004, 2007; Kostic & Cleary, 2009); ours is the first to suggest spatial configuration of one's surroundings as one of these features. As suggested by the Gestalt familiarity hypothesis, déjà vu rates were higher when the test scenes configurally mapped onto studied scenes than when they did not.

Perhaps most importantly, déjà vu is specifically defined as a sense of oldness alongside the realization that the situation is new (Brown, 2004), yet no published studies have modeled this in the laboratory. We discovered that participants could simultaneously identify a configurally similar novel scene as new, yet report increased familiarity and associated déjà vu, indicating a simultaneous sense of newness contrasted with a feeling of familiarity.

Experiment 2's design change allowed us to more closely examine the hypothesis that feature-matching (Clark & Gronlund, 1996) drives scene familiarity in the absence of recall. Indeed, among scenes called "new," reported familiarity was greatest for those actually studied compared to those that were new (both configurally similar and not). Thus, the greater the degree of match to a memory representation, the greater the assessed familiarity. The déjà vu rates mirrored this pattern.

Given that our images were created with one software package (SIMS 2), there is some degree of similarity (Cleary et al., 2007) among all stimuli, even between scenes not intentionally designed to resemble each other. Such inter-stimulus similarity probably accounts for our somewhat elevated base rates. More specifically, new scenes not designed to configurally map onto studied scenes still share some general design similarities to studied scenes by virtue of all scenes being created using the same 3D gaming software using the same VR system. However, counterbalancing items across treatment conditions assured that this potential base-rate elevation did not compromise our between-condition finding that familiarity and déjà vu were lowest in the configurally dissimilar condition, higher in the configurally similar condition, and highest in the identical condition among scenes called new. Thus, the greater the degree of resemblance to a prior experience, the greater the familiarity for a situation thought to be new, as feature-matching theory would predict.

Some may wonder whether the déjà vu experience produced in the laboratory is identical to that which occurs spontaneously in day-to-day life. In the same way that laboratory studies of familiarity may not duplicate the exact "butcher-on-the-bus" experience (e.g., Mandler, 2008) in real life, laboratory induced déjà vu experiences may not duplicate the often-uncanny experience that many report spontaneously experiencing. That said, survey research suggests considerable variation in the quality of the déjà vu experience with respect to type and intensity of affective reaction (see Brown, 2004), and an intense sense of weirdness may not be a defining property of all déjà vu experiences. As with research on other subjective states, such as tip-of-the-tongue experiences, we assume that our participants are monitoring their personal reactions in a way that allows them to report on when a subjective experience seems like déjà vu. Indeed, self-reports on surveys about déjà vu constitute most of what is currently known about the phenomenon. Furthermore, college students show the highest déjà vu rates in survey research (Brown, 2004); thus, they comprise a population that should be particularly able to self-report experiences of déjà vu. Our 3D virtual reality stimuli were designed to appear much closer to life-like visual experiences than in prior research, so our déjà vu experiences should be closer to natural ones when compared to prior laboratory research paradigms.

Ours is the first study to empirically support the idea that the configuration of objects in 3-dimensional space can produce familiarity in the absence of recall, and to suggest that this may be related to déjà vu. In addition, our findings demonstrate the viability of VR technology to study these topics in experimental settings. Not only do our results suggest that findings such as those of Cleary et al. (2009) are reliable, but the value of full-environment 3D color-scene immersion was confirmed by the strong effect of our similarity manipulation (configural resemblance) on déjà vu rates and our larger effect sizes compared to Cleary et al.'s (2009) effect size using 2D black-and-white stimuli. Also contributing to this difference may be the fact that Cleary et al. examined general similarity, whereas we focused on a more specific type of similarity in spatial configuration. Finally, though we find support for scene element configuration as a type of feature that can produce familiarity and contribute to déjà vu, undoubtedly, there are other types of features of scenes, events and situations that can also contribute. Future research should aim to identify these other types of features.

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