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Learning and using knowledge about what other people do and don't know despite amnesia

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Abstract

Successful communication requires keeping track of what other people do and do not know, and how this differs from our own knowledge. Here we ask how knowledge of what others know is stored in memory. We take a neuropsychological approach, comparing healthy adults to patients with severe declarative memory impairment (amnesia). We evaluate whether this memory impairment disrupts the ability to successfully acquire and use knowledge about what other people know when communicating with them. We tested participants in a referential communication task in which the participants described a series of abstract “tangram” images for a partner. Participants then repeated the task with the same partner or a new partner. Findings show that much like healthy individuals, individuals with amnesia successfully tailored their communicative language to the knowledge shared with their conversational partner—their common ground. They produced brief descriptions of the tangram images for the familiar partner and provided more descriptive, longer expressions for the new partner. These findings demonstrate remarkable sparing in amnesia of the acquisition and use of partner-specific knowledge that underlies common ground, and have important implications for understanding the memory systems that support conversational language.

Keywords

common ground; partner-specific dialogue; amnesia; hippocampus; declarative memory

Successful communication requires keeping track of what other people do and do not know, and how this differs from our own knowledge. In conversation, we store memorial

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representations of what information we know and that we know our conversational partner also knows. This mutually known information is termed *common ground*. For communication to be successful we must distinguish what is common ground from information that we know but that our partner does not (Clark, 1992). Everyday language use relies on this distinction. For example, we tailor our language, providing more (to a colleague: *My favorite aunt Annie is here!*) or less background information (to my brother: *Annie's here!*), depending on how much common ground is held with one's communication partner (Brennan & Clark, 1996; Wilkes-Gibbs & Clark, 1992). Critically, what is common ground with one person may not be common ground with another person. Thus common ground must be bound in memory to specific partners.

Previous studies demonstrate that healthy young adults are sensitive to their current conversational partner's knowledge state and, when speaking, design utterances accordingly (Wilkes-Gibbs & Clark, 1992; Schober & Clark, 1989). A standard paradigm for examining these *audience design* processes (Clark & Murphy, 1982) is the referential communication task (Krauss & Weinheimer, 1966) in which a speaker describes a series of abstract images to a partner multiple times across a series of trials. The classic finding is that with repeated reference to the same images—and, critically, with the same partner—the speaker's referring expressions used to describe these images become more concise. These brief referring expressions are considered to be part of the communication partners' common ground. When talking to a new partner, speakers use longer, more descriptive expressions to accommodate the new partner's lack of knowledge. While this ability to bind common ground to specific conversational partners is well attested in healthy young adults (Brennan & Clark, 1996; Wilkes-Gibbs & Clark, 1992), little is known about how common ground is represented in memory (Brown-Schmidt & Duff, 2016). According to classic theories of language use, *episodic* (declarative) memory plays a central role in theories of common ground, as it allows us to query memory for events that we shared with specific individuals (Clark & Marshall, 1978). Here we describe the first direct test of the hypothesis that episodic memory underlies representations of partner-specific common ground by comparing healthy adults to adults with bilateral hippocampal damage and severe episodic memory impairment (amnesia). We evaluate whether amnesia precludes the ability to successfully form and use common ground when communicating.

Individuals with amnesia show dramatic impairment in acquisition of new episodic/declarative memories, including severe impairments in acquiring new knowledge of major events and details of their personal lives (Eichenbaum & Cohen, 2001). Notable are failures in acquiring novel arbitrary relations (e.g., stimulus and its location on screen; Konkel, Warren, Duff, Tranel, & Cohen, 2008) or orthographic word form and conceptual meaning; Gabrieli, Cohen, & Corkin, 1988). Yet, remarkably, individuals with amnesia can acquire novel referential labels in a communicative task where they describe abstract “tangram” images for a partner (Duff, Hengst, Tranel & Cohen, 2006; Duff, Gupta, Hengst, Tranel, & Cohen, 2011; Duff, Hengst, Tranel, & Cohen, 2008b; see Figure 1 for example images). Thus, when supported by the infrastructure of a communicative task, and when the descriptions are self-generated and non-arbitrary (‘siesta man’ for image that looks like a person reclining), individuals with amnesia can acquire novel mappings between images and referential labels.

While Duff and colleagues interpreted these findings as evidence for formation of common ground, an alternative interpretation of this remarkable sparing of learning must be considered. The challenge is this: there is no direct evidence that individuals with amnesia did, in fact, form common ground with their partners. Instead, it is possible they acquired image-label mappings, but failed to associate the mappings as common ground with a specific partner. That is, for this learning to be considered common ground, the individuals with amnesia would need to also encode that the image-label mappings were associated with a specific communication partner. One reason to seriously consider this alternative interpretation comes from an analysis of *referential form* (Duff et al. 2011). Healthy comparison participants frequently used *definite* expressions like “*the camel*” after describing the same image several times with the same partner, whereas individuals with amnesia were significantly more likely to use *indefinite* expressions like “*a camel*”. This might have come about if the spared learning in amnesia reflected a change in how they viewed the image, as if it now looks like “*a camel*”. If so, this would reflect a very different type of representation than the one that allows a healthy person to know that both they and their discourse partner know the name of this particular image. Critically, while an impressive feat of learning for individuals with amnesia, a change in how the person with amnesia viewed the objects that was not bound in memory with the discourse partner would not constitute common ground.

Here we ask if common ground can be formed in the absence of episodic memory for newly experienced events. In the experiment, participants described a series of abstract tangram images multiple times with one partner, establishing brief referential labels for each image, e.g. “camel”, “ballet dancer”, et cetera. Then, participants continued the task for several more rounds with either the same partner, or a new partner. If individuals with amnesia can establish common ground, we would expect them to produce short descriptions when continuing to converse with the same partner who has common ground for these image labels. When talking to a new partner, amnesic speakers should produce longer descriptions in order to accommodate the new partner’s lack of knowledge for these image-label mappings (Wilkes-Gibbs & Clark, 1992; Schober & Clark, 1989). However, if common ground cannot be formed when episodic memory is severely impaired, individuals with amnesia should continue to use the brief labels acquired with the familiar partner when communicating with new partners as well. Additional analyses examine the form of the participants’ referential labels, evaluating the rate at which they use definite vs. indefinite determiners (i.e., “the” vs. “a/an”). When information is common ground, it is typically referenced with definite referring expressions; we ask whether individuals with amnesia successfully mark shared knowledge with definite determiners.

Methods

Participants

Eight people participated in the study: four individuals with bilateral hippocampal damage and severe declarative memory impairment and four healthy adult participants. Etiologies of the patients with amnesia included anoxia/hypoxia (1846, 2363, 2563) resulting in bilateral hippocampal damage, and herpes simplex encephalitis (HSE) (1951), resulting in more

extensive bilateral medial temporal lobe damage affecting the hippocampus, amygdala, and surrounding cortices. High-resolution volumetric MRI data were available for three patients (excluding 2563) and revealed significant reduction to the hippocampus bilaterally with volumes reduced by at least 2.64 studentized residuals compared to age matched healthy comparison participants (Figure 2). Visual inspection of a CT scan from patient 2563, who wears a pacemaker, confirmed damage limited to hippocampus.

Performance on tests of neuropsychological functioning revealed a severe and selective impairment in episodic/declarative memory functioning while performance across other cognitive domains was within normal limits (Table 1). The Wechsler Memory Scale–III General Memory Index scores for each participant were at least 25 points lower than their scores on the Wechsler Adult Intelligence Scale–III, and the mean difference between Full Scale IQ and General Memory Index was 38.5 points. The average Delayed Memory Index was 58.0, which is 3 standard deviations below population means. This deficit in episodic/declarative memory was observed in the context of otherwise intact cognitive abilities. Participants performed within normal limits on standardized neuropsychological tests of intelligence, verbal IQ, semantic knowledge, language, and executive function. The intact performance on tests of naming, fluency, and semantic information in the patients with amnesia, together with their lack of aphasia, suggests that lexical and semantic access is within normal limits as measured by standard neuropsychological testing and that the verbal demands of the task do not pose a disproportionate challenge for the patients.

Comparison participants were four healthy individuals matched pairwise on age, handedness, sex, and education. All participants were native, monolingual speakers of North American English with normal or corrected-to-normal hearing and vision. They did not have a history of neurological, psychiatric, or psychological disease or any history of learning or other developmental disability.

In addition, we collected pilot data from 16 healthy, native-English speaking undergraduates at the University of Illinois at Urbana-Champaign in order to vet the task¹. These healthy young adults had normal hearing and normal or corrected-to-normal vision.

Procedure

Participants were tested individually in a referential communication task. The task involved communicating with one of two experimenters. During the task, the voices of both the participant and experimenter were recorded with a digital audio recorder (Marantz PMD670) and a Shure omnidirectional microphone. A video recording was made as well as a backup. The experimenters were assistants in the lab, one male and one female, who were blind to experimental hypotheses. The experimenters played the role of *Matcher* in the task, which involved following a series of instructions produced by the participant speaker. For consistency, the female assistant always played the role of Matcher #1, and the male played the role of Matcher #2.

¹Due to time constraints, undergraduate participants completed 4 blocks of testing (4 sets of tangrams; vs. 16 sets for patients and their comparisons).

At the beginning of the task, the participant was given a booklet that had 8 abstract tangram images on each page. The participant was asked to describe each tangram to the experimenter who played the role of *Matcher #1*; meanwhile the other experimenter (*Matcher #2*) waited in another room. *Matcher #1* was seated in front of a computer screen, viewing the same 8 tangrams in a different order (see Figure 1). The *Matcher's* job was to re-arrange the tangrams following the participant speaker's instructions such that their tangrams were in the same order. During the task, the participant and *Matcher* faced each other so they could see their faces and gestures, however the computer and booklet were positioned so that they could not see each other's tangram images. Thus the task required the partners to use linguistic communication in order to complete the task.

Once the participant had finished describing the 8 tangrams in order, they moved to the next round of the task. On the next round, the participant and the *Matcher* sorted the same 8 tangrams into a new order following the same procedure as before. The task was interactive and the partners were allowed to freely talk and ask questions of each other as needed. The *Matcher* waited until the participant completed his/her description of each tangram, waiting to provide feedback until the participant had finished their description. Altogether, participants repeated this sorting task with the same 8 tangrams across 9 rounds of gameplay.

The participant always completed rounds 1–5 with *Matcher #1*. The primary experimental manipulation was the identity of the *Matcher* during rounds 6–9. After the 5th round, *Matcher #1* always left the room and closed the door. After a short break (~2 minutes), one of the two matchers returned to the room: In the different-*Matcher* condition, *Matcher #2* entered the room and completed the same task with the participant for rounds 6–9. In the same-*Matcher* condition, *Matcher #1* returned to continue the task with the participant for rounds 6–9.

Each participant completed the 9-round sorting task 16 different times—each time with a different set of 8 tangrams (128 tangrams total). Having each participant complete the task 16 different times allowed us to use a within-subjects manipulation of the same-*Matcher* vs. different-*Matcher* variable: Each participant completed the 9-round sorting task with 8 sets of tangrams in the same-*Matcher* condition and 8 different sets of tangrams in the different-*Matcher* condition (the odd-numbered sets were in the same-*Matcher* condition, and the even-numbered sets were in the different-*Matcher* condition). If the participant could not finish the 16 sets in a single day, the task was spread out across two days², though critically all trials for a given set were always completed within the same testing session on the same day. The entire experiment took approximately 2 hours for healthy comparison participants and 3.5–5.5 hours for participants with amnesia. The tangram stimuli were adapted from Slocum (2004). Because some participants had previous experience labeling other tangrams (Duff et al. 2006), we made sure to use a new group of 128 tangrams in the present experiment.

²Description length (our primary dependent measure) did not differ across the two days ($t=1.62$, $p>.05$).

Analysis

The audio recordings of the voices of both the participant and Matcher during the referential communication task were transcribed by a research assistant. The majority of the conversation involved the participant describing, in order, his or her tangrams, and the Matcher responding with confirmatory feedback (e.g., *OK*), or a clarification question (e.g., *You mean...?*) (Table 2). The participant's description of each tangram was identified within the transcript, and the number of words used to describe each tangram was counted. The length of the participant's description of each tangram was quantified as the total number of words used to describe each tangram, including all function (e.g., "the") and content words (e.g., "bowtie") in the description. Excluded from the word count were lexical disfluencies (e.g., "uh" and "um"). In our primary analysis, the dependent measure was the number of words, in total, that the participant used to describe each tangram, even if those words were spread out across several turns. For example, this word count included all words in (1) and (2), with the exception of disfluencies (*italicized*) and speech of the Matcher (**bolded**).

1. "that looks like *uh* back to back trapezoids with arrows *er* triangles pointed down **does it kind of look like a butterfly** it could be a butterfly"

word count = 17

2. "Just a post **a post?** **What else?** Maybe a holder or a mailbox holder at the end of a driveway or something there"

word count = 19

A potential concern with this *full description length* measure is that the Matcher's verbal feedback could have prompted the speaker to use more words in one condition over the other. To address this possibility we conducted a supplemental analysis in which we examined the participant's *initiating reference* to each tangram. The initiating reference was the participant's very first attempt to describe each tangram, and included only those words produced before the Matcher provided any feedback (see Duff et al., 2006). Thus the utterances that are analyzed in this supplemental analysis occurred before the Matcher could have prompted the participant (e.g., *What?*) to provide additional information. Note that Matchers typically produced few words in the task, and these contributions were not analyzed.

We also coded the form of the referential expressions. The referential expressions were coded for whether the speaker used a definite expression (e.g., *"the duck"*), an indefinite expression (e.g., *"a duck"*), a description (e.g., *"it looks like a flying duck with...."*), or a bare noun (e.g., *"duck"*). Following Duff et al. (2011), definite noun phrases and bare nouns were grouped together in the "definite" category for the purposes of statistical analysis.

Statistical analyses were conducted using mixed effects models that were fit in R (version 3.2.2) using the lme4 package (version 1.1–10). Models were initially fit with random intercepts for both subjects and items and the maximum number of random slopes justified by the experimental design in order to take by-subject and by-item variability into account. In cases where the maximal model failed to converge, a backwards-fitting procedure was used to identify the model with the largest random effects structure that would converge

(Barr, Levy, Scheepers, & Tily, 2013). Categorical fixed effects were coded with mean-centered Helmert contrasts.

Results

The analyses focus on two main dependent measures: (1) the *full description length* of the participant's reference to each tangram, along with a supplemental analysis of description length examined the length of just the *initiating reference*; and (2) whether the referring expression was definite (e.g., *the bowtie*), or not (e.g., *a bowtie*).

Description Length

We analyzed description length in two separate, planned analyses. The first analysis examined the predicted referential shortening across Rounds 1–5, during which the participant established short labels for each tangram with Matcher #1. The second analysis examined whether the participant changed the way in which he or she referred to the tangrams as a function of the identity of the Matcher (same Matcher vs. new Matcher) in Round 6. To evaluate sensitivity to the new Matcher, the second analysis focused on the *change* in the length of the referring expression between Round 5 (before the potential change in the Matcher), and Round 6, where the identity of the Matcher was manipulated.

The first analysis examined the full description length in Rounds 1–5 (see Figure 3) and included group (Amnesia vs. healthy comparison) and Round (1–5) as mean-centered fixed effects. Across the first five rounds, the average number of words used to describe each tangram decreased ($z = -12.59$, $p < .0001$; Table A1), demonstrating successful learning of image-label mappings in individuals with amnesia ($z = -6.54$, $p < .0001$). A significant interaction between participant Group and Round ($z = 4.11$, $p < .0001$) was due to a more rapid decrease in description length in the healthy comparison group. While healthy comparison participants were faster to develop brief descriptions of the tangrams, when analyzed separately, both healthy comparison participants ($z = -11.46$, $p < .0001$) and individuals with amnesia ($z = -6.54$, $p < .0001$) showed a significant effect of Round. This finding demonstrates that participants in both groups successfully established brief referential descriptions for the tangrams. This result replicates previous findings by Duff et al. (2006) that individuals with amnesia successfully designed and remembered novel labels for abstract tangrams.

Do individuals with amnesia represent common ground? To answer this question, the second analysis focused on the effect of the partner: The critical test comes from situations where a new partner joins the task in round 6 (i.e., the difference in the number of words between Rounds 5–6 when a new partner joins; Figure 4, Table A2). The analysis included Group (Amnesia vs. healthy comparison) and condition (same-Matcher and different-Matcher) as mean-centered fixed effects. A significant effect of condition was due to the use of longer expressions when addressing the new Matcher vs. addressing the same Matcher ($t = 6.79$, $p < .0001$). The interaction between group and condition was not significant ($t = -1.18$, $p = .26$), and when each group was analyzed separately, both healthy comparison participants ($t = 6.72$, $p < .0001$), and individuals with amnesia ($t = 4.13$, $p < .001$) showed a significant effect of condition. This result shows that individuals with amnesia, much like healthy comparison

participants, are sensitive to the new Matcher's lack of knowledge, and accommodate their naiveté by elaborating previously established descriptions.

Our sample of 16 young adults similarly showed a robust effect of partner, with a significantly larger increase in the number of words between Rounds 5–6 in the different-Matcher than in the same-Matcher condition (8.38 vs. 2.75, $t = 4.42$, $p < .001$). This effect was driven by longer expressions in the different-Matcher ($M = 13.19$, $SD = 11.07$) than the same-Matcher condition ($M = 8.39$, $SD = 5.94$) on Round 6, and replicates earlier findings with young adults in this paradigm (Yoon & Brown-Schmidt, 2017).

Initiating reference length

A potential concern with our interpretation of the findings is that the Matcher could have influenced the participant's referential descriptions. For example, if Matchers in the different-Matcher condition were more confused, it is possible that participants could have produced additional descriptive words in reaction to this confusion, and not due to a participant's representation that the Matcher lacks knowledge per se. While we think this is unlikely (the new matcher in the different-Matcher condition was familiar with the task), this possibility is important to rule out³.

The participant's initiating reference — their first attempt to describe each tangram, before any feedback (Duff et al. 2006) — was examined to test whether the acquisition and partner-specific use of reference was evident in the participant's referential descriptions before the Matcher had a chance to provide feedback. Two mixed-effects models were fit in the same way as before, in order to test for (1) a reduction in initiating description length across the first five Rounds, and (2) the effect of the partner, comparing the change in initiating description length between Rounds 5–6 as a function of Matcher condition. Consistent with the primary analysis, a significant effect of Round showed that the average length of expressions gradually decreased as common ground for the referential expressions was established across the first five Rounds ($z = -49.85$, $p < .0001$; Table A3). As in the primary analysis, an interaction with Group ($z = 20.26$, $p < .0001$) was due to a more robust learning effect in healthy comparison participants ($z = -44.94$, $p < .0001$) compared to individuals with amnesia ($z = -23.31$, $p < .0001$).

The second analysis examined the change in description length between Rounds 5 and 6, and again revealed a significant effect of condition ($t = 5.59$, $p < .0001$; Table A4), due to a larger increase in description length with different vs. same Matchers. This analysis also revealed an interaction with participant Group ($t = -2.60$, $p < .05$), due to a larger effect of condition for healthy comparison participants ($t = 5.99$, $p < .0001$) than individuals with amnesia ($t = 2.62$, $p < .05$). Critically, however, individuals with amnesia did show a significant effect of condition, demonstrating that their initial referential design process was

³We also examined number of conversational turns that the participant and experimenter used to complete the task. In the 5th round of the task, conversations in the amnesia group involved more turns than the comparison group (amnesia: 2.93 turns vs. comparison: 1.80; $t = 3.01$, $p < .05$). In the 6th round, there were overall more turns in the different-Matcher condition (amnesia: 4.90 vs. control: 2.84), compared to the same-Matcher condition (amnesia: 3.08 vs. control: 1.93; $t = 3.69$, $p < .05$), an effect that was seen in both participant groups. Note that the number of turns is, unsurprisingly, correlated with total number of words used on a given trial ($r = 0.67$).

influenced by the common ground that they did (or did not) share with the current conversational partner. Thus, individuals with amnesia adjusted their use of language based on what their partner did and did not know rather than because the images simply *looked that way* to them.

The young adult sample similarly showed a significant effect of condition on the change in description length between Rounds 5 and 6 ($t = 4.59$, $p < .001$); when speaking with the new partner, young adults used significantly longer expressions.

Referential Form

The referring expressions used to describe the tangrams were categorized into one of four different categories: definite (e.g., “*the duck*”), indefinite (e.g., “*a duck*”), a description (e.g., “*it looks like a flying duck with....*”), or a bare noun without an article (e.g., “*duck*”). Following Duff et al. (2011), we combine definite expressions and bare nouns into the “definite” category. A binary measure of whether or not the referential description was definite was analyzed in a series of logit-link mixed effects models.

The first model examined the change in the rate of definite expressions across Rounds 1–5. Analyses of referential form revealed that participants used more definite expressions as the task progressed ($t = -4.82$, $p < .0001$, Table A5, Figure 5), consistent with formation of common ground. Individuals with amnesia used overall fewer definite expressions across these first five Rounds (Amnesia: 49% definite; Comparison: 70% definite; $z = -2.33$, $p < .05$). There was also an interaction with group ($z = 2.50$, $p < .05$). While both groups showed increased rates of definite expressions across rounds, the effect was larger for healthy comparison participants ($z = -4.99$, $p < .0001$) than it was for the amnesia group ($z = -1.72$, $p = .09$).

The second model examined the condition effect in Round 6, which was when either the same Matcher or a new Matcher returned to the room. In Round 6, a significant effect of condition was due to participants using fewer definite expressions with the new, naïve Matcher compared to the old Matcher ($z = 7.22$, $p < .0001$, Table A6). Participants in both groups tended to use indefinite or long descriptions when addressing the new Matcher (see Figure 6). While there was no overall difference between the groups at Round 6 ($z = .74$, $p = .46$), an interaction with participant group ($z = -3.29$, $p < .001$) was due to a larger and more consistent effect of condition for healthy comparison participants (same-Matcher: 87% definite vs. different-Matcher: 19% definite, $z = 11.97$, $p < .0001$), compared to individuals with amnesia (same-Matcher: 64% definite vs. different-Matcher: 31% definite, $z = 7.38$, $p < .0001$). This finding is consistent with the idea that hippocampal episodic memory contributes to some aspects of common ground (Duff et al. 2011). We also observed that there was considerable variability in the magnitude of the Matcher effect among participants in the amnesia group (Figure 7). Whereas every comparison participant showed the Matcher effect, in patients 1846 and 1951 the effect was quite small and the overall rate of definite referring expressions was low.

Finally, the young adult participants' use of definite expressions showed a significant partner effect, with more definite expressions in the same-Matcher (83% definite) than in the different-Matcher condition (36% definite $z = 3.99$, $p < .001$).

Discussion

Individuals with amnesia show remarkable sparing in the ability to learn what other people do and do not know, and flexibly tailor their conversational language use based on this knowledge. Just like healthy comparison participants and young adults, individuals with amnesia used brief labels to describe images for a partner who also knew these labels. When addressing a new, naive partner, they used longer indefinite descriptions. There was no evidence that individuals with amnesia designed expressions simply because the objects *looked that way* to them. If so, they would have used similar descriptions for both the same and different partners. Instead, individuals with amnesia, like the healthy participants, adjusted their use of language based on what their partner did and did not know. These findings suggest that common ground information can be acquired in the absence of declarative memory.

How is it that individuals with amnesia successfully acquired and used common ground in a partner-specific manner? Classic theories of common ground emphasize the role of episodic (declarative) memory mechanisms in binding the record of past experience with the individuals who share common ground for those experiences (Clark & Marshall, 1978). Access to the episodic record supports strategic querying of past experiences, e.g., "*Annie, do you remember when the dog ate the Thanksgiving turkey?*". Given the severity of the episodic memory impairment, as documented by their performance on standardized neuropsychological memory assessment (Table 1) and in our interactions with them over the past 16 years, they did not rely on an episodic record. For example, on one occasion, while working with a participant with amnesia, the second author (MCD) dropped a pencil and climbed under the desk to retrieve it. When she reappeared just moments later the amnesic individual was startled, inquiring as to from where she came. Thus, it is unlikely that the patients were able to encode or maintain in episodic memory the relationship between a given partner and the description for each of the images over multiple rounds.

Some other mechanism, then, must support their ability to design language in a way that reflects common ground shared with the discourse partner. One possibility is that during encoding, individuals with amnesia formed a unitized or fused relation between each image, label, and partner—an ability linked with non-declarative memory (Ryan, Moses, Barense, & Rosenbaum, 2013). Non-declarative representations can be composed of multiple elements blended into an inseparable or unitized representation (Eichenbaum & Cohen, 2001; Henke, 2010). The *original* partner may have functioned as a cue to support retrieval of this fused representation. In contrast, the *new* partner would fail to cue this information, given that individual elements of a unitized representation cannot be reactivated (Eichenbaum & Cohen, 2001; Henke, 2010). The idea that partners serve as contextual cues has been suggested as an explanation for how speakers can be sensitive to common ground without explicitly recalling their shared history (Horton & Gerrig, 2005a). A unitization account offers compelling explanatory power for these findings. Such an interpretation predicts that

in the absence of the ability to activate the constituent pieces individually, performance of individuals with amnesia might lack flexibility across time and contexts. If a unitization mechanism were at work here, it may also offer an explanation for why individuals with amnesia were less successful at using definite reference to mark common ground. While the original partner may have successfully cued retrieval of a unitized representation of a tangram image and its brief description, e.g., “*bowtie*”, a lack of awareness that this referential description was in fact shared knowledge, may have prevented individuals with amnesia from using definite reference to signal common ground.

While individuals with amnesia demonstrated sparing in the ability to use partner specific knowledge, their performance differed from that of healthy individuals, particularly in the use of definite reference to mark common ground. This observation is consistent with the proposal that hippocampal-dependent declarative memory does make contributions to common ground (Duff et al. 2011), and that in healthy individuals both declarative and non-declarative systems work together to support common ground based processes (Brown-Schmidt & Duff, 2016). Critically, then, the import of the present work is that the ability to bring to mind past events – a process dependent on episodic (declarative) memory – is not required to flexibly use common ground in conversation. This is a finding that could not have been made by studying healthy participants alone as in healthy individuals, both memory systems likely work in concert to support functional memory use in everyday settings such as conversation.

The current findings also shed new light on previous studies of learning in amnesia outside of language. Consider the Swiss physician Claparède who hid a pin between his fingers while greeting his amnesic patient with a handshake (Claparède, 1911). The pinprick elicited some pain but shortly the patient ceased to recall the experience. However, Claparède reports his patient refused to subsequently shake his hand, and when pressed replied that *there are sometimes pins hidden in hands*. Observations like these point to preserved affective associations for different interactional partners (as measured by avoidance responses or forced-choice preference judgments) (Claparède, 1911; Tranel & Damasio, 1993). What is unknown, however, is the specificity of the association between the individual, the knowledge acquired, and the subsequent behavioral response. That is, did Claparède’s patient refuse to shake all hands, or just his? Our findings suggest the refusal would be limited to him. Moreover, the fact our findings come from the domain of language suggest that this form of preserved learning extends beyond pure affective or emotional processes.

These data also offer a richer characterization of the memory-language interface and a fresh look at patterns of spared and impaired language ability in amnesia. A prominent model of memory contributions to language (Ullman, 2004) posits hippocampal declarative memory contributions to the lexicon, and basal ganglia procedural memory contributions to the grammar (cf. Vargha-Khadem et al., 1997; Schapiro et al., 2014, respectively). While critical in establishing predictions and demonstrations of spared and impaired language ability in amnesia, such simplistic mappings fail to account for the full range of communicative activities characteristic of everyday language use (e.g., acquiring and using knowledge about what communication partners do and don’t know). Such mappings also do not account for evidence demonstrating pervasive hippocampal contributions to language use and processing

(e.g., Duff & Brown-Schmidt, 2012, in press; MacKay et al., 1998; Piai et al., 2016) or attempts to understand the unique contributions of multiple memory systems to a single behavioral phenomenon (e.g., word learning, Gupta, 2011) and how a single memory system supports seemingly distinct behaviors (e.g., hippocampal support for statistical learning and episodic memory, Schapiro et al., 2016). Findings here revealing preserved ability to develop and flexibly use partner specific knowledge while failing to mark such knowledge with definite references in amnesia provides new evidence for the idea that multiple memory systems make complementary contributions to common ground processes in language use (Brown-Schmidt & Duff, 2016) and to language use and processing more broadly. We suggest consideration of the orchestration of memory systems in meeting the demands of complex communicative behaviors will move the study of the memory-language interface towards more representative, biologically plausible, and ecologically valid models of memory-and-language-in-use in every-day settings.

In presenting the current, and former (Duff et al., 2006), findings of sparing in the acquisition of referential labels in amnesia we are frequently asked about a possible role for fast-mapping in the patients' success. Fast mapping refers to the immediate association of a novel word with an unfamiliar visual stimulus when referenced in the context of familiar visual competitors and has been linked to early word learning abilities (Carey & Bartlett, 1978; Horst & Samuelson, 2008). Interest in a possible connection to fast mapping was bolstered by a demonstration of spared fast mapping in hippocampal amnesia (Sharon, Moscovitch, & Gilboa, 2011; although see Smith, Urgolites, Hopkins, & Squire, 2014; Warren & Duff, 2014). While the Sharon et al., (2011) study and our work both deal with referential learning in amnesia, there are several notable differences. In Sharon et al. (2011), amnesic participants were taught arbitrary, novel word-picture associations in the context of familiar stimuli and learned these mappings rapidly over only a couple of trials. By contrast, the present observation of spared learning is situated in a naturalistic conversational task in which the acquired image-label mappings are generated in a social context, over many repetitions, and the labels are generated from previously acquired semantic information. An open question is whether fast mapping would support the partner sensitivity observed in the present research.

In summary, the finding that individuals with episodic amnesia successfully acquired and used knowledge about what specific discourse partners do and do not know makes a clear case against the episodic memory system as being necessary and sufficient for common ground. More generally, interactive communication may provide a potent learning environment that serves to facilitate effective communication. Our findings suggest that in disorders of memory involving hippocampal damage, including Alzheimer's disease, it may be possible to build, and use representations of common ground with specific communication partners, even if the patient fails to recall their shared experiences. Such preserved ability has tremendous clinical implications for maintaining successful communication and improving communicative lives of patients and their communication partners.

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APPENDIX

Table A1
Full description length as a function of Round (Rounds 1–5)

Poisson family mixed effect model, fit by maximum likelihood (Laplace Approximation). Fixed effects were Round (1–5, where Round 1 is treated as baseline), and a mean-centered fixed effect for participant Group (amnesia vs. control). The dependent measure is the number of words used by the participant to describe each image. Analyses based on 4942 observations, 128 items and 8 subjects.

	Estimate	SE	z-value	p-value		Variance	SD
<i>Fixed</i> (intercept)	2.789	0.074			<i>Random</i> <i>Item</i> (Intercept)	0.194	0.441
Round	−0.282	0.022	−12.590	<.0001		Round	0.015
Group	0.058	0.138	0.430	0.671		Group	0.381
Round*Group	0.174	0.042	4.110	<.0001	<i>Subject</i> Round*Group	0.033	0.183
					(Intercept)	0.031	0.176
					Round	0.003	0.054

Table A2
Full description length as a function of partner (Round 5 vs. 6)

Linear mixed effect model fit by REML. Condition (same-Matcher vs. different-Matcher) and group (amnesia vs. control) are mean-centered fixed effects. The dependent measure is difference in the number of words used to describe each image, between Rounds 5 and 6. Significance of fixed effects based on Satterthwaite approximations to the df. Analyses based on 994 observations, 128 items and 8 subjects.

	Estimate	SE	df	t-value	p-value		Variance	SD
<i>Fixed</i> (intercept)	3.571	0.437				<i>Random</i> <i>Item</i> (Intercept)	8.156	2.856
Condition	6.110	0.900	26.770	6.791	<.0001		Condition	17.170
Group	−0.132	0.690	32.440	−0.191	0.849		Group	12.630
Condition*Group	−1.693	1.435	12.410	−1.180	0.26	<i>Subject</i> (Intercept)	0.052	0.229
						Condition	0.525	0.725
						<i>Residual</i>	86.698	9.311

Table A3
Initiating reference length as a function of Round
(Rounds 1–5)

Poisson family mixed effect model, fit by maximum likelihood (Laplace Approximation). Fixed effects were Round (1–5, where Round 1 is treated as baseline), and a mean-centered fixed effect for participant Group (amnesia vs. control). The dependent measure is the number of words used by the participant to describe each image in the first conversational turn for that image (the participant's responses to feedback from the Matcher are not included in this model). Analyses based on 4942 observations, 128 items and 8 subjects.

	Estimate	SE	z-value	p-value		Variance	SD
<i>Fixed</i> (intercept)	2.421	0.070			<i>Random</i> <i>Item</i> (Intercept)	0.102	0.320
Round	−0.198	0.004	−49.850	<.0001	Group	0.091	0.301
Group	0.001	0.132	0.010	0.991	<i>Subject</i> (Intercept)	0.032	0.179
Round*Group	0.160	0.008	20.260	<.0001			

Table A4
Initiating reference length as a function of partner
(Round 5 vs. 6)

Linear mixed effect model fit by REML. Condition (same-Matcher vs. different-Matcher) and group (amnesia vs. control) are mean-centered fixed effects. The dependent measure is difference in the number of words used to describe each image, between Rounds 5 and 6, and is limited to words used in the first conversational turn for that image. Significance of fixed effects based on Satterthwaite approximations to the df. Analyses based on 994 observations, 128 items and 8 subjects.

	Estimate	SE	df	t-value	p-value		Variance	SD
<i>Fixed</i> (intercept)	0.868	0.464				<i>Random</i> <i>Item</i> (Intercept)	17.341	4.164
Condition	3.218	0.576	25.501	5.587	<.0001	Condition	10.134	3.183
Group	−1.011	0.652	11.405	−1.551	0.148	Group	13.556	3.682
Condition*Group	−2.419	0.930	16.166	−2.600	0.019	<i>Subject</i> (Intercept)	0.260	0.510
						Condition	0.296	0.544
						<i>Residual</i>	35.033	5.919

Table A5
Definite article rate as a function of Round (Rounds 1–5)

Logit mixed effect model, fit by maximum likelihood (Laplace Approximation). Fixed effects were Round (1–5, where Round 1 is treated as baseline), and a mean-centered fixed effect for participant Group (amnesia vs. control). The dependent measure is a binary measure of whether or not the referential description was definite. Analyses based on 4942 observations, 128 items and 8 subjects.

	Estimate	SE	z-value	p-value		Variance	SD
<i>Fixed</i> (intercept)	2.527	0.343			<i>Random</i> <i>Item</i> (Intercept)	0.275	0.524
Round	–1.226	0.255	–4.818	<.0001	<i>Subject</i> Group	0.268	0.518
Group	–1.580	0.680	–2.325	<.05	(Intercept)	0.826	0.909
Round*Group	1.270	0.508	2.498	<.05	Round	0.497	0.705

Table A6
Definite article rate as a function of partner (Round 6)

Logit mixed effect model, fit by maximum likelihood (Laplace Approximation). Condition (same-Matcher vs. different-Matcher) and group (amnesia vs. control) are fixed effects. The dependent measure is a binary measure of whether or not the referential description on Round 6 was definite. Analyses based on 994 observations, 128 items and 8 subjects.

	Estimate	SE	z-value	p-value		Variance	SD
<i>Fixed</i> (intercept)	–0.203	0.471			<i>Random</i> <i>Item</i> (Intercept)	0.253	0.503
Condition	3.398	0.471	7.215	<.0001	<i>Subject</i> (Intercept)	1.614	1.271
Group	0.688	0.931	0.739	0.46	Round	1.117	1.057
Condition*Group	–2.985	0.907	–3.291	<.001			

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Highlights

- Learning about what others do and do not know is spared in amnesia.
- Patients with amnesia can flexibly tailor utterances for specific partners
- Common ground can be acquired independently from declarative memory

Figure 1.
Example tangrams.

Figure 2.

Magnetic resonance scans of hippocampal patients. Images are coronal slices through four points along the hippocampus from T1-weighted scans. Volume changes can be noted in the hippocampal region for patients 1846 and 2363 and significant bilateral MTL damage including the hippocampus can be noted in patient 1951. R = right, L = left, A = anterior, P = posterior, NC = healthy comparison brain.

Figure 3. Full description length

Average number of words used by participants to describe each image in the same-Matcher and the different-Matcher conditions.

Figure 4. Full description length as a function of partner
 Difference in number of words used to describe each tangram between Rounds 5–6.

(a) Healthy comparison participants (b) Individuals with amnesia

Figure 5. Referential Form during Rounds 1–5

Average proportion of each referential form category produced by (a) healthy comparison participants (left) and (b) individuals with amnesia (right). For the purpose of statistical analysis, “definite” and “no article” are combined.

Figure 6.
Referential Form in the same-Matcher and different-Matcher conditions in Round 6. For the purpose of statistical analysis, “definite” and “no article” are combined.

(a) Healthy comparison participants (b) Individuals with amnesia

Figure 7.
Referential Form shown for each participant separately in the same-Matcher and different-Matcher conditions in Round 6. Individual with amnesia (right) and each healthy comparison participant (left).

Demographic and neuropsychological characteristics of the patients with episodic amnesia

Table 1

	Sex	Hd.	Age	Ed.	ET	HC Vol	WAIS -III FSIQ	WMS- III GMI	AVLT Delay	CFT Delay	WAIS- III Vocab	WAIS- III Info	Fluency	TT	BNT	WCST Cat
1846	F	R	51	14	Anoxia	-4.23	84	57	3	6	8	8	98%	41	43	6
1951	M	R	62	16	HSE	-8.10	106	57	2	4	10	11	96%	44	49	6
2363	M	R	58	18	Anoxia	-2.64	98	73	0	0	12	13	97%	44	58	6
2563	M	L	59	16	Anoxia	N/A *	102	75	1	7	9	12	100%	44	57	6
3 M		3 R	57.5	16.0		-5.0	96.5	58.0	1.5	4.3	9.8	11	98%	43.3	51.8	6.0
1 F		1 L	± 4.6	± 1.6		± 2.8	± 9.2	± 11.5	± 1.3	± 3.1	± 1.7	± 2.2	± 0.02	± 1.5	± 7.1	± 0.0
Summary																

Note. M = Male; F = Female; Hd = handedness; Ed = education; ET = Etiology; HSE = Herpes simplex encephalitis; HC Vol = studentized residual differences in hippocampal volume relative to a matched comparison group (see Allen et al., 2006; Buchanan et al., 2005);

* = Visual inspection of a CT scan from patient 2563, who wears a pacemaker, confirmed damage limited to hippocampus; WAIS-III = Wechsler Adult Intelligence Scale; FSIQ = Full Scale Intelligence Quotient, WMS-III GMI = Wechsler Memory Scale-III; GMI = General Memory Index; AVLT = Auditory Verbal Learning Test, 15 min delay score; CFT = Complex Figure Test, recall score; Fluency = Animal fluency; TT = Token Test; BNT = Boston Naming Test; WCST = Wisconsin Card Sorting Task; Cat = Number of categories achieved out of six. **Bolded** scores are impaired as defined as 2 or more standard deviations below normative data.

Table 2

Descriptions of a single tangram image by a participant with amnesia across Rounds 1–6 in the same-Matcher (left) and different-Matcher conditions (right). The critical manipulation is whether the same or a new partner joins the conversation in Round 6. Bold text indicates speech of the communication partner.

<div><div>•</div><div><u>same-Matcher condition</u></div><div>(top left image; Fig. 1, left panel)</div><div><div>1</div><div>number two is a funny shape with a uh that looks like a uh trap er yeah trapezoid on thee left side um and it's got opposing uh v figures oh yeah does it have a box cut out of it yeah ok</div><div>.</div><div>.</div><div>.</div><div>5</div><div>number five is thee white square yep cut out</div><div>[Matcher leaves and the <i>same</i> Matcher returns]</div><div>6</div><div>thee white cut out square cut out yep is number two</div></div></div> <td><div><div>•</div><div><u>different-Matcher condition</u></div><div>(top left image; Fig. 1, right panel)</div><div><div>1</div><div>its kind of like a tie uh huh like a necktie kinda of like a bowtie type thing it has two points in the middle coming down does it have two points going up like that too uh huh ok is it like a bird also yeah</div><div>.</div><div>.</div><div>.</div><div>5</div><div>looks like kind of like the bow tie mmhm</div><div>[Matcher leaves and a <i>new</i> Matcher returns]</div><div>6</div><div>seventh looks like a bowtie kind of like comes to a point comes yep yeah good down and has the bow tie look then at the bottom got it</div></div></div></td>	<div><div>•</div><div><u>different-Matcher condition</u></div><div>(top left image; Fig. 1, right panel)</div><div><div>1</div><div>its kind of like a tie uh huh like a necktie kinda of like a bowtie type thing it has two points in the middle coming down does it have two points going up like that too uh huh ok is it like a bird also yeah</div><div>.</div><div>.</div><div>.</div><div>5</div><div>looks like kind of like the bow tie mmhm</div><div>[Matcher leaves and a <i>new</i> Matcher returns]</div><div>6</div><div>seventh looks like a bowtie kind of like comes to a point comes yep yeah good down and has the bow tie look then at the bottom got it</div></div></div>
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