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An object memory bias induced by communicative reference

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Abstract

In humans, a good proportion of knowledge, including knowledge about objects and object kinds, is acquired via social learning by direct communication from others. If communicative signals raise the expectation of social learning about objects, intrinsic (permanent) features that support object recognition are relevant to store into memory, while extrinsic (accidental) object properties can be ignored. We investigated this hypothesis by instructing participants to memorise shape-colour associations that constituted either an extrinsic object property (the colour of the box that contained the object, Experiment 1) or an intrinsic one (the colour of the object, Experiment 2). Compared to a non-communicative context, communicative presentation of the objects impaired participants' performance when they recalled extrinsic object properties, while their incidental memory of the intrinsic shape-colour associations was not affected. Communicative signals had no effect on performance when the task required the memorisation of intrinsic object properties. The negative effect of communicative reference on the memory of extrinsic properties was also confirmed in Experiment 3, where this property was object location. Such a memory bias suggests that referent objects in communication tend to be seen as representatives of their kind rather than as individuals.

Keywords: object memory, communication, extrinsic properties, intrinsic properties

Highlights

- The effect of communicative reference on the memory for object properties was tested.
- Intrinsic properties were automatically encoded.
- The encoding of extrinsic properties was impeded by communicative signals.
- This bias could support social learning by communication.

Classification:

- 2300 Human Experimental Psychology
- 2343 Learning & Memory

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1. Introduction

Visual object perception is partially guided by the intention we bear towards the objects in question. This is well documented by studies on the contrast between the two visual pathways, where the ventral pathway processes information related to the identity of objects while dorsal pathway takes care the location and/or action-relevant properties of objects (Mishkin, Ungerleider, & Macko, 1983; Milner & Goodale, 1995; Shmuelof & Zohary, 2005). If an object is the potential target of a motor action, its location, orientation and other action-relevant properties get special attention (Jeannerod, 2006). These properties tend to be temporary and accidental, i.e., extrinsic to the object, and are processed by the dorsal visual pathway. In contrast, if the object is to be recognised or categorised, its intrinsic and permanent properties are more relevant to pay attention to. Object features such as shape, colour, texture, and their conjunctions are among these properties, and are primarily processed by the ventral visual pathway.

Whereas intrinsic features are involuntarily processed during object recognition, the storing of extrinsic features in memory usually requires voluntary access. This is shown by findings that intrinsic object features mainly influence their familiarity, while extrinsic features have an impact on episodic recollection (Ecker, Zimmer & Groh-Bordin, 2007). That the encoding of extrinsic object features is not automatic but requires voluntarily attention is also supported by experiments showing that when location is irrelevant, it gets encoded only for approximately 1000 msec, but it is not retained in the more stable short term visual memory (Jaswal & Logie, 2011). Furthermore, studies on ageing also demonstrated a dissociation between memory for extrinsic and intrinsic properties: while older adults had a specific and disproportionate deficit in recognition memory for location, in the case of item or colour information their performance remained intact (Chalfonte & Johnson, 1996). Thus, even though spatial attention is required for feature binding (Treisman, 1998), it seems that the encoding of location information for long-term storage requires voluntary attention (Naveh-Benjamin, 1988).

However, object perception is not only determined by voluntary intentions but is also influenced by contextual factors. For example, compared to non-communicative contexts, the location (an extrinsic property) of objects presented as potential referents of non-verbal communication tends to be ignored, while the encoding of their visual features is not affected and may even be facilitated. This has been shown in change detection studies, in which attention was drawn to objects by communicative or non-communicative means, and then change detection performance was measured after either the location or the visual features of the objects (or neither) were modified (Marno, Davelaar, & Csibra, 2014; Yoon, Johnson, & Csibra, 2008). These studies revealed that both infants and adults were less likely to detect the location change of an object that served as the referent of previous communication, but communication did not impair, and in some cases did facilitate, the detection of identity change. This effect is explained by a theory according to which ostensive communication automatically triggers readiness to learn generic information about potential referents embedded in communication (Csibra & Gergely, 2009). The content of human communication extends well beyond the ‘here and now’ in several respects (Csibra & Gergely, 2011). It can express information about distant or absent events and entities, and about past, future, and hypothetical states of affairs (Deacon, 1997). Crucially, it can also convey information not just about single entities but about a whole class of them, for example in generic linguistic expressions (Carlson & Pelletier, 1995). It has been suggested that such statements about kinds of entities can also be expressed non-verbally using an exemplar as a medium (Csibra & Shamsudheen, 2015). Such communication about kinds allows those who are addressed to learn, for example, a property of a whole class of objects by revealing this property in a single exemplar.

When someone learns about a kind of object from experiencing an exemplar, only those properties of the object are relevant to encode that support subsequent recognition of objects of the same kind. These properties tend to be the permanent, non-accidental, intrinsic properties of the object. In contrast to these, the properties that only apply to the exemplar (for example, its location) are irrelevant and could be ignored. Thus, if communication about an object elicits the expectation of learning something about its kind, attention to its intrinsic properties should be prioritised over attention to extrinsic properties in communicative compared to non-communicative contexts (Marno et al., 2014; Yoon et al., 2008).

However, the above studies demonstrated only that communicative contexts modulate the attention to certain object features. If the function of this modulatory influence is to facilitate learning, the effect has to last longer than a few seconds and should also be evident in long-term object memory. The present study tested this prediction by exposing participants to a series of objects in a communicative or non-communicative context and instructing them to memorise an extrinsic or intrinsic property of them. We have developed a paradigm in which the objects are individuated by shape, and the to-be-memorised intrinsic and extrinsic properties represented by the same quality: colour. We chose colour as the property to be associated with shapes because it can serve as an intrinsic property (the colour of the object individuated by its shape) and an extrinsic property (the colour of the box hiding the shape). Participants were presented with a series of novel 2D shapes, and were instructed to form associations between these shapes and the colour of the box from which they emerged (an extrinsic property, Experiment 1), or the colour of the shapes themselves (an intrinsic property, Experiment 2). This design intended to overcome the shortcoming of earlier studies, in which the relevant intrinsic and extrinsic properties were realised in different visual features (appearance vs. location), which are processed by distinct visual streams (ventral vs. dorsal). After completing the instructed task, we asked participants to identify, as an unexpected 'surprise' task, the other type of colour-shape association to test whether they had incidentally encoded it. By using an instructed as well as a surprise task, we measured what information the participants encoded both voluntarily and incidentally in order to test the prediction that communicative signals modulate the encoding of only the intrinsic colour-shape associations when if these associations were irrelevant. Given that our focus was to show a processing trade-off due to the context of the presentation, both sides of this trade-off function needed to be measured.

In addition, Experiment 3 tested whether communicative reference has the same effect on memorising object location (an extrinsic object property) as does a colour associated with this location.

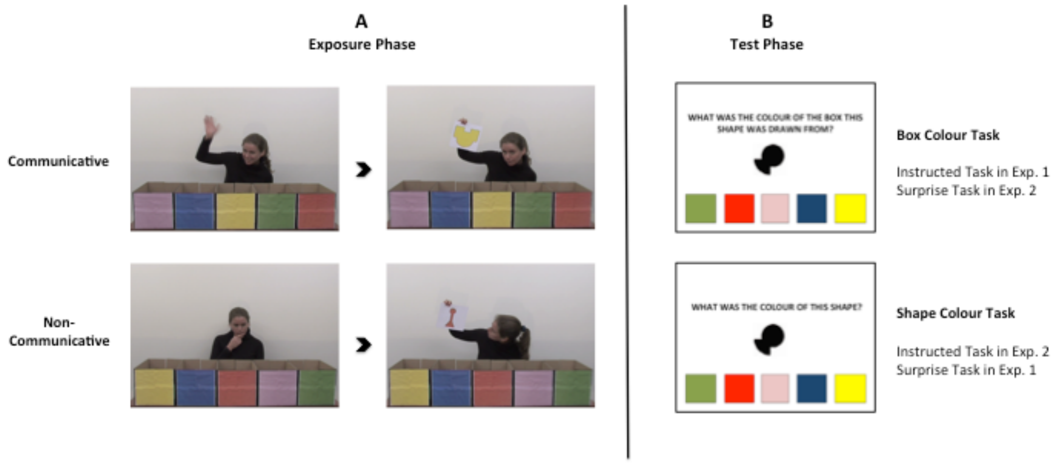
All experiments were performed by two groups of participants. One group observed the shapes in a communicative context, while the other had the same amount of exposure to the shapes but without communicative signals. We predicted that establishing communicative reference to an object would automatically draw attention away from extrinsic object features and hence would impair memory performance when the task required remembering such properties. We also predicted that communicative reference would facilitate the forming of shape-colour bindings within objects, hence better memory for intrinsic object properties revealed in the surprise task in Experiments 1 and 3.

2. Experiment 1: Memorising an Extrinsic Object Property

2.1. Methods

2.1.1. Participants. Forty volunteers (25 females; mean age = 20.5 years) participated in the experiment. The sample size was chosen on the basis of our previous study (Marno et al., 2014), which investigated of a different effect of the same underlying process we targeted in this experiment. Half of the subjects participated in the Communicative Condition, and half of them were assigned to the Non-Communicative Condition. All of them had normal or corrected to normal visual acuity.

2.1.2. Stimuli. Sixteen video clips were created for both the Communicative and the Non-Communicative conditions (see Fig 1A). Each clip showed an event sequence, in which an actress took a sheet of paper, depicting a coloured shape, from one of 5 coloured boxes, and then returned it to the same location. The actress sat behind a table with the 5 boxes arranged horizontally next to each other. The boxes were coloured blue, green, yellow, red, and pink, and were arranged in different orders in each clip. Within each condition, every clip included a different shape, which was coloured in one of the same 5 colours used for the boxes, but never in the same colour as the box from which it was drawn.



In the Communicative condition, the actress first looked into the camera (establishing eye contact with the participant), waved her hands and smiled (5 s), looked at the boxes and then chose one (2 s), took a sheet from it and lifted it such that the viewer could see the shape (5 s), looked at the shape (2 s), looked again into the camera (2 s), put the sheet back into the same box (3 s), and finally looked down to the table (1 s). In the Non-communicative condition, the actress first rubbed her chin while looking at the boxes (indicating that she was hesitating about her choice, 5 s), looked at the boxes and chose one (2 s), took a sheet from it and lifted it such that the viewer could see the shape (5 s), looked at the shape (2 s), put the sheet back into the same box (5 s), and finally looked down to the table (1 s). Thus, clips in both conditions lasted 20 s, and provided the same amount of exposure to the shapes and the boxes. The difference between conditions was whether the actress sent communicative signals towards the viewer before (eye contact, waving) and after (looking back at the viewer) revealing the shape drawn onto the sheet. These signals were intended to convey her referential intention to the viewer, while nothing more was expressed about the object and hence the content of her communication remained ambiguous.

2.1.3. Procedure. The experiment consisted of two phases. Before the exposure phase, participants were instructed to watch the clips and attempt to memorise which shape would come from which box. They were explicitly told that the location of the boxes would be shuffled in each clip and they should identify the boxes by their colour. They were presented with 16 clips in a row on a 15" touch-screen with 2 s break in between. Immediately after the exposure phase, the participants' memory for shape-box colour associations was probed in the test phase. During the test trials, they were presented with one of the 16 shapes they had been exposed to, but in black colour, and a row of 5 coloured squares (colours corresponding to box colours in the exposure phase). To the question “What was the colour of the box this shape was drawn from?”, participants responded by touching the square with the colour of their choice without time constraints (Fig 1B). The order of the shapes in the test trials was different from that of the exposure phase and was randomised for each participant.

After completing the test phase, participants were told by the experimenter that there would be another, "surprise" task to test whether they could identify the colours of the shapes themselves, which they were not instructed to memorise. They were presented with another 16 trials similar to the test phase, but this time with the question ”What was the colour of this shape?” and they were requested to respond the same way as in the previous test phase (Fig 1B). The order of the presentation was randomised each time. The whole experiment lasted approximately fifteen minutes (depending on the speed of the responses).

2.1.4. Data analysis. We measured two types of dependent variable: (i) the percentage of correct colour identification in the test phase and in the surprise task, and, (ii) within the incorrect responses, the percentage of intrusions — responses that picked the other colour associated with the given shape (i.e., the shape colour in the instructed task and the box colour in the surprise task).

2.2. Results

Fig 2A shows the average performance of the two groups in the instructed task (box colour task) and in the surprise task (shape colour task). We analysed these data in a 2x2 ANOVA with Task (box colour vs. shape colour) as a within-subject factor and Condition (communicative vs. non-communicative) as a between-subject factor. We found that Task had a significant main effect [$F(1, 38) = 5.829$, $p = .021$, $\eta^2 = .133$], due to the better overall performance in the instructed task than in the surprise task. The interaction between Task and Condition was also significant [$F(1, 38) = 9.419$, $p = .004$, $\eta^2 = .199$], suggesting that the presence of communicative cues modulated colour associations differently in the two tasks. In particular, this interaction was due to the fact that participants in the non-communicative condition performed better in the instructed task than in the surprise task [$t(19) = 4.500$, $p < .001$], while in the communicative condition no such difference was found [$t(19) = 0.413$, $p = .684$]. Conversely, participants in the non-communicative condition outperformed those in the communicative condition in the instructed box-colour task [$t(38) = 2.771$, $p = .009$] but not in the surprise shape-colour task [$t(38) = 1.019$, $p = .314$].

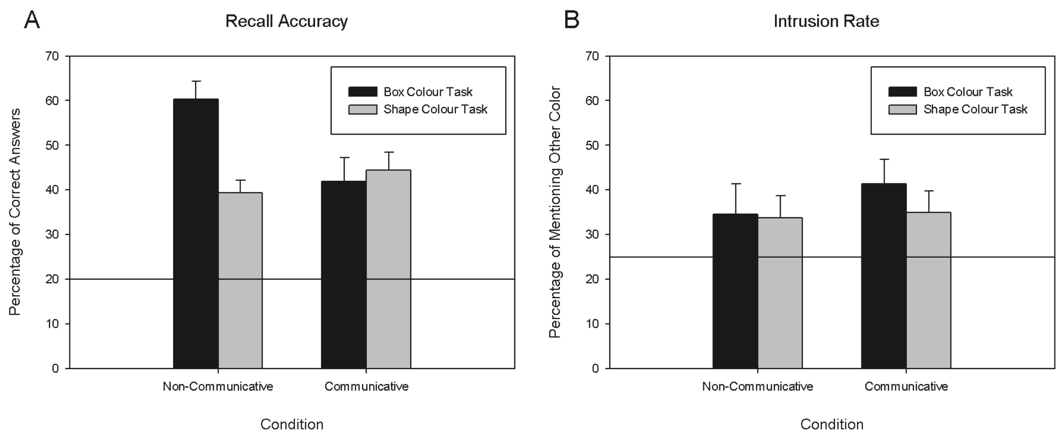


Fig 2B shows the average amount of intrusions as a function of task and condition. An ANOVA with the same design as we used on performance data yielded no significant effects. However, we also compared the proportion of intrusions to the theoretical chance level (25%) with the assumption that incorrect answers could have come from any of the four additional colours. These analyses indicated that only the participants in the communicative condition, and only in the instructed box-colour task, produced more intrusions than what would have been expected by chance [$t(19) = 2.995$, $p = .007$ with Bonferroni corrected alpha-level of .0125]. Thus, when participants were instructed to memorise associations between shapes and box-colours, they tended to form associations between a shape and its own colour — but only in the communicative context.

2.3. Discussion

Our study required the participants to form shape-colour associations, but these associations represented an extrinsic object property (location) rather than an intrinsic one. We found that forming these associations was much more difficult when the objects in question were potential referents of participant-directed communication. However, in the surprise task, in which participants were requested to report colour-shape associations that represented an intrinsic property, the communicative context did not impair the formation of these associations. In fact, participants in the communicative condition did not perform better in the instructed task, which required recalling accidental shape-colour associations, than in the surprise task, in which they recalled permanent, object-bound links between shapes and colours.

Our other prediction, according to which communicative reference would facilitate memory for intrinsic object properties even when this is not required by the task was not confirmed by the results: The performance in the surprise task was not better in the communicative than in the non-communicative condition. We will return to a possible explanation of this negative result in the General Discussion. The absence of such facilitative effect of communicative signals would suggest that these signals exerted only a negative effect on memory. However, the errors that the participants produced suggest that the communicative signals also had a slight positive effect on the formation of associations between shapes and their colours. When the participants answered incorrectly in the non-communicative condition, their choice of colour was evenly distributed among the four incorrect colours, whether they attempted to identify the colour of the shape or of the box. This suggests random guessing of some information not encoded in their memory. We found a similar pattern of guessing in the communicative condition when the task was the identification of the colour of the shape. However, when the participants performed the instructed task in the communicative condition, they responded with the colour of the shape at a higher level than chance. We interpret this intrusion of the irrelevant colour information as indicating that the communicative context made the participants encode the colour of the shapes even in trials in which they failed to pay attention to the task-relevant box-colour information. Note, however, that this effect was only evident when compared to chance level but was not significantly different from the intrusion rates in the other conditions. This should make us cautious in interpreting this effect as specific to the association to be formed and to the context in which these associations are presented.

Nevertheless, while the intrusion rates might have indicated that the communicative context facilitated the encoding of intrinsic object properties even when they were not task-relevant, the stronger, and even striking, effect was the negative influence of communication on the instructed task. This finding raises the possibility of an alternative explanation, according to which communicative signals, rather than shifting attention from extrinsic to intrinsic properties, simply prevented the participants from focusing on the task. In order to test such an interpretation of the results, we conducted another experiment, in which we instructed the participants to memorise the colours of the shapes.

3. Experiment 2: Memorising an Intrinsic Object Property

3.1. Methods

The methods of Experiment 2 were identical to Experiment 1 in all respects, except that we instructed participants to memorise the colours of the shapes, and the surprise task required them to identify the colours of the boxes associated with the shapes.

3.1.1. Participants. Forty volunteers (23 female; mean age = 25.0 years) participated in the experiment. Half of them participated in the Communicative Condition, and half of them were assigned to the Non-Communicative Condition. All of them had normal or corrected to normal visual acuity.

3.1.2. Procedure. In the exposure phase, we instructed the participants to memorise the colour of each of the shapes. In each of the test trials, they were presented with one of the 16 shapes in black colour and a row of 5 coloured squares (colours corresponding to shape colours in the exposure phase). Participants were requested to answer the question “What was the colour of this shape?” by touching the square with the colour of their choice. After completing the test phase for the instructed task, we told the participants that there would be another task to test whether they could identify the colours of the boxes from which each shape had been drawn. They were presented with a further 16 trials similar to the test phase, but this time with the question ”What was the colour of the box this shape was drawn from?” and they were requested to respond the same way as in the previous test phase (Fig 1B).

3.2. Results

Fig 3A shows the average performance of the two groups in the instructed task (shape colour task) and in the surprise task (box colour task). We analysed these data in a 2x2 ANOVA with Task (shape colour vs. box colour) as a within-subject factor and Condition (communicative vs. non-communicative) as a between-subject factor. We found that Task had a significant main effect [$F(1, 38) = 294.775$, $p < .001$, $\eta^2 = .886$], due to the better overall performance in the instructed task than in the surprise task. Neither the effect of Condition nor the interaction between Task and Condition had a significant effect on performance, suggesting that the presentation context did not modulate colour associations in either task. In effect, performance in the instructed (shape colour) task was very good (approaching 80% hit rate), and in the surprise (box colour) task was close to chance level (20% hit rate).

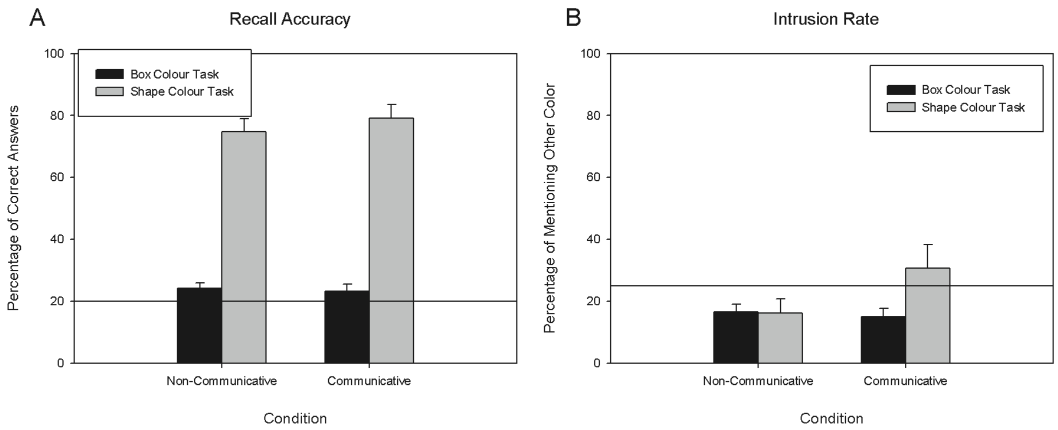


Fig 3B shows the average amount of intrusions as a function of task and condition in Experiment 2. An ANOVA with the same design as we used on performance data yielded no significant effects, although both the effect of Task [$F(1, 38) = 3.366$, $p = .074$, $\eta^2 = .081$] and the interaction between Task and Condition [$F(1, 38) = 3.653$, $p = .064$, $\eta^2 = .088$] approached significance. When we compared the proportion of intrusions to the theoretical chance level (25%), these analyses indicated that when the task was to identify the colour of the box associated with the shapes, participants produced intrusions of shape colours significantly below chance level both in the Communicative [$t(19) = 3.662$, $p = .002$] and in the Non-Communicative [$t(19) = 3.304$, $p = .004$] conditions (with Bonferroni corrected alpha level of .0125). On the other hand, intrusion rates in the box colour task were not different from chance level in either condition [Communicative Condition: $t(19) = 0.758$, $p = .458$; Non-Communicative Condition: $t(19) = 1.935$, $p = .068$].

3.3. Discussion

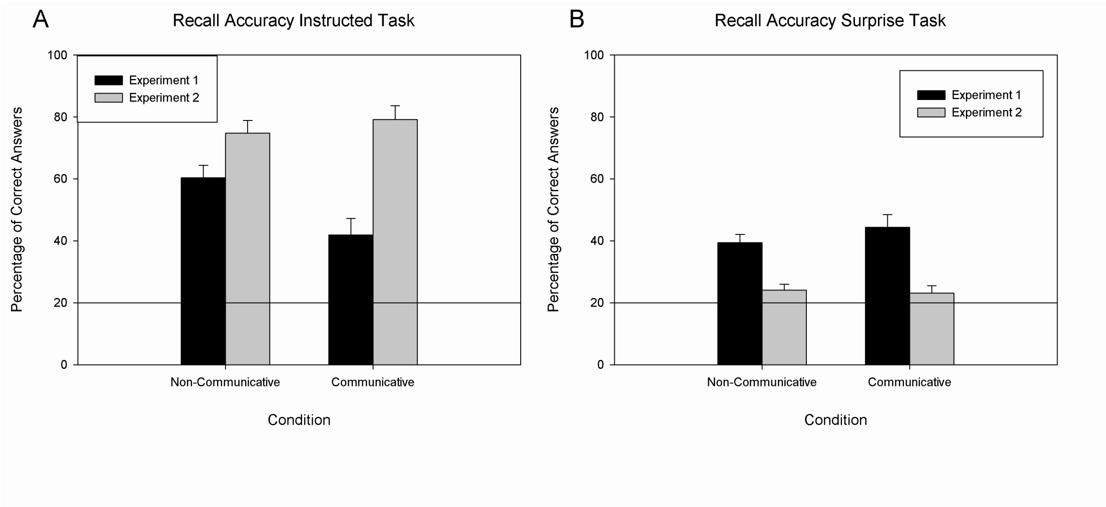
Unlike in Experiment 1, communicative signals had no effect on memory performance in the instructed task, which required the encoding of intrinsic shape-colour associations. Although the facilitation of the forming of these associations by communicative reference might be predicted by our hypothesis, the absence of such influence is explained by excellent performance in this task. Even in the non-communicative condition, the participants correctly identified the colour of 12 out of 16 shapes after a single exposure to each, and so the communicative context could exert only a non-significant increase on this performance. However, the fact that the communicative signals did not impair the performance in this task indicates that the poor performance in the communicative condition of Experiment 1 was not due to an unspecific distracting effect of communicative signals on memorising task-relevant associations.

Communicative signals did not have an effect on the intrusion rates either. Rather, we found that the intrusion rates were below the chance level when the box colours had to be identified. This is explained by the fact that the participants almost always remembered the colours of the shapes correctly (shown by their performance in the instructed task), and avoided choosing these colours when they guessed the colour of the corresponding boxes. Such an effect suggests that, although they did not encode the specific colours of the boxes from which the shapes were drawn, the participants incidentally noticed the implicit rule that the colour of the shape and the colour of the corresponding box never matched. Thus, the participants did pay attention to the boxes, but in the absence of explicit instruction, they were not compelled to encode the relation between their colour and the shape they were hiding.

4. Comparison Across Experiments 1 and 2

In two experiments, we manipulated the communicative context and employed a surprise memory test. The experiments differed in terms of the instruction of the to-be-memorised property (extrinsic vs. intrinsic). According to the position advanced here, we expected a bias to encode intrinsic object properties irrespective of instruction, and that this bias would get accentuated in a communicative context. We also expected that a communicative context would make it difficult to encode extrinsic object properties, even when this is the explicit task.

For ease of comparison, Fig 4 shows the accuracy in both the instructed and the surprise memory tasks as a function of communicative context and explicit instruction. In the instructed tasks (Fig 4A), we found an overall advantage for encoding shape colour over box colour [$F(1,76) = 32.564$, $p < .001$, $\eta^2 = .300$], and this advantage was much larger in the communicative context [interaction: $F(1,76) = 6.374$, $p = .014$, $\eta^2 = .077$]. Performance for the surprise tasks (Fig 4B) shows that the memory for shape-colour was better than for box-colour [$F(1,76) = 40.544$, $p < .001$, $\eta^2 = .348$], irrespective of communicative context.



These cross-experiment analyses suggest a general bias for encoding intrinsic features irrespective of communicative context in both intentional and incidental memory. Extrinsic object features were only encoded when participants were explicitly instructed to do so, but communicative reference interfered with this task.

One can, however, object to the conclusion that the locus of the effect of interference of communicative reference is the encoding of extrinsic features on the basis that the colour of the box containing an object is not an extrinsic feature of the object. Indeed, this colour is identified only via first identifying the location of the object in question, and as such, it is a property (colour) of a property (location) of the object, which may not normally be bound directly to the object. It is thus possible that communicative reference interferes with the process of this second-order binding process and not with the binding of an extrinsic feature to the object.

To resolve this ambiguity, we decided to contrast memory for intrinsic colour information directly to memory for location. While location is thought to be crucial for initial perceptual binding (Logie, Brockmole & Jaswal, 2011), the encoding of location information does not always happen in an automatic way, but it may require conscious effort (Naveh-

Benjamin, 1988). Thus, if we predict that communication facilitates the encoding of generalisable, inherent object properties, and that this facilitatory effect is produced in the expense of memorising extrinsic features, then remembering of the location of objects should be relatively impaired when the objects are presented in a communicative context, as opposed to when they are shown in a neutral context. Experiment 3 tested this prediction.

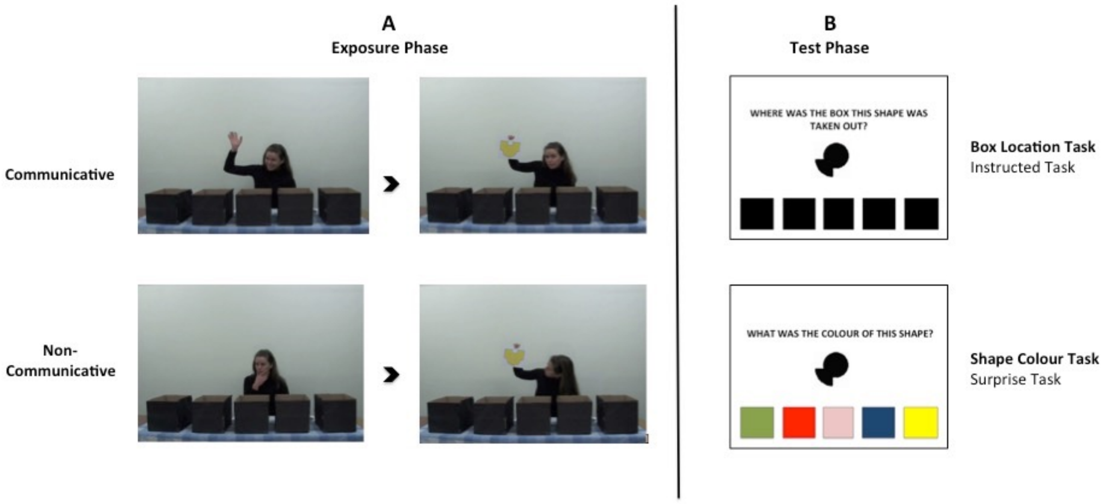
5. Experiment 3: Memorising the Location of Objects

5.1. Methods

The methods of Experiment 3 were identical to Experiment 1 in all respects, except that the boxes were all black, and that the participants were instructed to memorise the location of the boxes from which the shapes were taken.

5.1.1. Participants. Forty volunteers (28 females; mean age = 23.0 years) participated in the experiment. Half of them participated in the Communicative Condition, and half of them were assigned to the Non-Communicative Condition. All of them had normal or corrected to normal visual acuity.

5.1.2. Stimuli. Twenty video clips were created for both the Communicative and the Non-Communicative conditions (see Fig 5A). Each clip showed an event sequence, in which an actress took a sheet of paper, depicting a coloured shape, from one of 5 black boxes arranged in a row, and then returned it to the same location. Within each condition, every clip included a different shape, which was coloured either green, or yellow, or red, or pink or blue. In both conditions, the actress performed the same actions as in Experiment 1.



5.1.3. Procedure. In the exposure phase, we instructed the participants to memorise the location of the boxes from which the shapes were taken. In each of the test trials, they were presented with one of the 20 shapes in black and a row of 5 black squares, indicating the positions of the boxes during the exposure phase. Participants were requested to answer the question "Where was the box this shape was taken out?" by touching the corresponding square. After completing the test phase for the instructed task, we told the participants that there would be another task to test whether they could identify the colours of the shapes. They were presented with a further 20 trials similar to the test phase of Experiment 1, with the question "What was the colour of this shape?" and they were requested to respond by touching the square with the corresponding colour (Fig 5B).

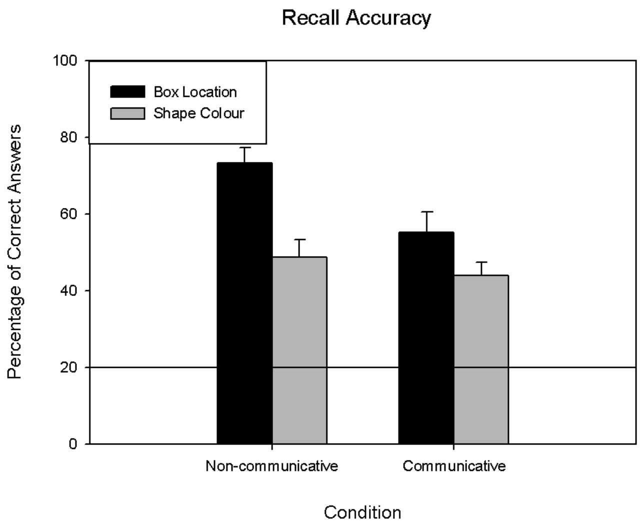
5.1.4. Data analysis. We measured the percentage of correct identification of box location in the test phase and the correct shape colour identification in the surprise task. As the information requested in the two tasks differed in nature (location vs. colour), we were unable to measure the amount of intrusions in this experiment.

5.2. Results and Discussion

Fig 6 shows the average performance of the two groups in the instructed task (box location task) and in the surprise task (shape colour task). We analysed these data in a 2x2 ANOVA with Task (box location vs. shape colour) as a within-subject factor and Condition (communicative vs. non-communicative) as a between-subject factor. We found that Task had a significant main effect [$F(1, 38) = 25.376$, $p < .001$, $\eta^2 = .400$], due to the better overall performance in the instructed task than in the surprise task. The interaction between Task and Condition was marginally significant [$F(1, 38) = 3.486$, $p = .070$, $\eta^2 = .084$]. However, while in both groups participants performed better in the instructed task than in the surprise task [$t(19) = 2.306$, $p = .033$, and $t(19) = 4.753$, $p < .001$ in the communicative and non-communicative condition, respectively], participants in the non-communicative condition remembered significantly better the locations of the boxes than those in the communicative condition [$t(38) = 2.733$, $p = .009$]. In the non-instructed shape colour task, however, we found no significant difference between the two conditions [$t(38) = 0.994$, $p = .326$].

In a further analysis, we investigated whether Experiments 1 and 3 produced the same results. We entered memory performance into a three-way ANOVA with Experiment (1 vs. 3) and Condition (communicative vs. non-communicative) as between-subjects factors, and Task (box location vs. shape colour) as a within subject factor. We obtained significant main effects of all the three factors [Experiment: $F(1,76) = 6.048$, $p = .016$, $\eta^2 = .074$; Condition: $F(1, 76) = 6.426$, $p = .013$, $\eta^2 = .078$; Task: $F(1, 76) = 35.988$, $p < .000$, $\eta^2 = .321$], and a significant interaction between Task and Condition [$F(1, 76) = 8.578$, $p = .004$, $\eta^2 = .101$]. The main effect of Task trivially shows that the participants performed better in the instructed task than in the surprise task in both experiments, and the main effect of Condition indicates that the non-communicative object presentation provided a better condition for memorisation that the communicative one. The interaction between Task and Condition demonstrates the predicted differential effect that communicative reference exerted on memorisation of intrinsic and extrinsic object properties. Crucially, while the main effect of Experiment indicates that remembering box locations is easier than remembering the colour of boxes (and it also interferes less with the incidental encoding of shape colours), this factor did not interact with the other factors, suggesting that the two experiments uncovered similar effects.

Thus, the results of Experiment 3 replicated the main findings of Experiment 1 by showing that communicative reference interferes with the encoding of extrinsic object properties, whether these properties manifest in location or colour information.



6. General Discussion

Objects do not usually change their colour or shape, and so these features, and their combinations, tend to be permanent, intrinsic properties of objects. This might be one of the reasons for why forming and remembering associations between shapes and colours are easier when they appear on the same object than when they belong to different ones (Lloyd-Jones & Nakabayashi, 2009; Xu, 2002; Walker & Cuthbert, 1998). Thus, when we instructed participants to memorise the colour of the shapes presented to them (Experiment 2), they performed this task easily (80% hit rate), while they displayed more difficulties when they had to associate shapes with box colours (Experiment 1: 60% hit rate). Note, however, that communicative presentation of the shapes modulated further this pre-existing preference for forming certain kinds of associations. Our participants tended to remember the colour of the shapes even when this was not task relevant (Experiment 1), and their memory could prioritise the formation of associations between shapes and box colours when this was their task and communication signals were not present. The communicative context, however, dramatically impaired the ability to perform this task (Experiment 1) as well as the ability to form shape-location associations (Experiment 3), while it had no effect on performing the other task that required identifying the colour of shapes (Experiment 2).

Because the tasks in Experiment 1 and 2 required memory for the same type of associations between shapes and colours, the effect of communication could not have been due to preferential processing, or ignorance, of certain visual features or feature combinations. Rather, the communicative context must have desensitised participants' attention, and consequently their memory, to the accidental association between the shapes and the colours designating locations, while leaving intact the (spontaneous and task-irrelevant) binding of the colours to the shapes themselves (in Experiment 1). The fact that Experiment 3 replicated the results of Experiment 1, i.e., that associating shapes to locations was similarly impaired by communicative reference as associating shapes to the colour of these locations, corroborates this conclusion.

Could it be that it was not the presence of the communicative signals in one condition, but the addition of different cues to the other condition, that produced the difference between conditions in Experiments 1 and 3? For example, the actor's initial hesitation as to which box to choose from might have increased attention to boxes in the non-communicative condition. However, at this point of the event the shape was not yet revealed, and the corresponding box colour could not have been linked to it. Also, this hesitation was present the same way in Experiment 2, where it did not produce an increased performance in incidental learning of box colours.

That communication would impair the memory of associations relevant only to the particular object present in the context had been predicted by a hypothesis about the expectations that communicative signals elicit in the addressee (Csibra & Gergely, 2009). The focus of this hypothesis is how addressees represent the referent: less likely as the object about which they are supposed to learn something, and more likely as an exemplar of a kind of object (Csibra & Shamsudheen, 2015). Note that further information embedded in the communication could clarify this point: some predicates are more applicable to particular objects than to object kinds. For example, if the actor had had two sheets with the same shapes on them, pointing to one of them could have invited a contrastive interpretation implying reference to the particular object rather than its kind. Our stimuli did not contain such information, and the intention of the communicator remained ambiguous. The stronger version of our hypothesis states that when the referent is ambiguous because the context or the predicate does not clarify its nature, people are biased to interpret the communicator's intention as using the object in the scene as a mere medium to refer to the kind it represents. In this case, the communicative signals might have implicitly suggested to the participants that the actor's communicative intention was to convey something about the shapes that was independent of where (from which box) they came from, which made them less attentive to the very information their task required them to memorise.

The weaker version of the hypothesis proposes that the communicative signals, rather than specifying the referent as the object kind, simply keep this option open when other aspects of the context leave the referent ambiguous. Thus, while keeping track of an object in a non-communicative setting (even if it is handled by a human agent, as in our study) is the easiest by its location, communicative reference raises the potential of receiving information that is relevant beyond the here-and-now and is unlikely to be linked to the particular location of the object. In this case, all potentially relevant features of the objects may be memorised, which makes it more likely that the task-relevant information (the colour of the box) becomes lost in the communicative condition than when this information is sufficient to individuate the object in the non-communicative condition.

Alternatively, one could hypothesise that communicative signals exert their effect by increasing the expected relevance of acquired information (Sperber & Wilson, 1995), rather than biasing the encoding and the memory of various object properties. However, in Experiment 1 the instruction explicitly defined an extrinsic object property (location) as relevant, whereas the intrinsic property of object colour was irrelevant to the task. Thus, the communicative principle of relevance would only account for our results if intrinsic object properties are always more relevant in communication than extrinsic ones, whatever information is sought by the addressee while performing a task. We find this interpretation unlikely, since it is quite common that extrinsic object properties (for example, the location of objects) become relevant, and are frequently communicated about (for example, when specifying the whereabout of objects) in everyday situations.

Our hypothesis predicted that communicative reference would not only interfere with the encoding of extrinsic object properties but would also facilitate the encoding of intrinsic ones. This prediction was not confirmed: the performance of identifying shape colours was not better in the communicative condition than in the non-communicative condition either when this was the surprise task in Experiment 1 or when this was the instructed task in Experiment 2. Although the intrusion data in Experiment 1 indicated a tendency in the predicted direction, this was a weak effect to support any firm conclusion. We speculate that the absence of such an effect was due to the fact that colour is rarely a kind-generalisable object property. Indeed, colour is irrelevant for the categorisation of most human-made artefact types, while shape is usually sufficient to identify exemplars (cf. the so-called ‘shape bias’, Landau, Smith, & Jones, 1988). Thus, by hindsight, if communicative reference facilitates the encoding of objects as exemplars of their kind, their colour may not be the most important information to include it in their representation. It is possible that another type of visual feature, such as object shape, which is usually more informative regarding object kind, could have resulted a stronger facilitatory effect of communicative signals in these experiments. However, if we had used shape as the critical feature to be encoded, some additional visual feature would have been needed to serve as a cue in the memory test. This design would have inevitably led to what is referred to as the cue-overload effect (Watkins & Watkins, 1976), which is the decrease in memory performance when more cues are added. This effect was shown to be so powerful that it could overshadow the effect of encoding/ retrieval match, which is the route through which cues exert their memory benefits. This effect has been discussed (Nairne, 2002) and demonstrated (Goh & Lu, 2011; Poirier, et al., 2012) in recent literature. Thus, choosing colour as the critical feature to remember was a trade-off between investigating our hypothesis and being able to create an experimental design that was likely to produce the desired effect.

While our finding demonstrates a negative effect of communication on the memory of extrinsic object properties, such as location or properties of location, we do think that this effect is normally balanced out by positive effects supporting optimal learning of information from communication. Relevant findings pointing to this direction are available in developmental psychology, where many recent studies have found better learning in communicative than in observational contexts (e.g., Butler & Markman, 2012; Egyed, Kiraly, & Gergely, 2013; Kiraly, Csibra, & Gergely, 2013). Future studies will clarify whether these positive effects of communication on learning extend to adult populations.

We have shown that ostensive communication modulates not only the attention to (Marno et al., 2014), but also the memory of, referent objects in a way that is conducive of learning about them. Note that we did not (and did not intend to) test what participants learnt in this study, only whether communicative signals interfere with long-term representation of object properties in a specific manner. While the positive side of this interference was only weakly confirmed by the elevated intrusion rates, the poor memory of extrinsic features of referent objects was a striking effect. The fact that such an effect is found even in a situation that explicitly solicits memorisation of extrinsic object properties suggests that humans are strongly tuned to receive generic information from each other in the context of communication. We believe that such bias may serve as a basis of acquiring cultural knowledge from others (Csibra & Gergely, 2011).

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Figure captions

Fig 1. Stimuli used in Experiments 1 and 2. A: representative frames from the videos presented to participants in the two conditions of the exposure phase. B: Examples of test trial displays presented on a touch-screen during the two tasks.

Fig 2. The results of Experiment 1. A: Average correct identification as a function of condition and tasks. B: Average amount of intrusion of irrelevant colour information as a function of condition and task. Error bars indicate SEM, and horizontal lines mark the theoretical chance level on both panels.

Fig 3. The results of Experiment 2. A: Average correct identification as a function of condition and tasks. B: Average amount of intrusion of irrelevant colour information as a function of condition and task. Error bars indicate SEM, and horizontal lines mark the theoretical chance level on both panels.

Fig 4. Average correct identification as a function of communicative context and task instruction for the instructed task (A) and the surprise task (B). Error bars indicate SEM, and horizontal lines mark the theoretical chance level on both panels. Note that these data repeat those presented on Figures 2 and 3.

Fig 5. Stimuli used in Experiment 3. A: representative frames from the videos presented to participants in the two conditions of the exposure phase. B: Examples of test trial displays presented on a touch-screen during the two tasks.

Fig 6. The results of Experiment 3. Average correct identification as a function of condition and tasks. Error bars indicate SEM, and horizontal lines mark the theoretical chance level.