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Deconstructing Social Interaction: The Complimentary Roles of Behaviour Alignment and Partner Feedback to the Creation of Shared Symbols

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Abstract

This paper experimentally tests the contribution of two distinct aspects of social interaction to the creation of shared symbols: behaviour alignment and concurrent partner feedback. Pairs of participants (N= 120, or 60 pairs) completed an experimental-semiotic game, similar to Pictionary, in which they tried to communicate a range of recurring meanings to a partner by drawing on a shared whiteboard (without speaking or using numbers of letters in their drawings). The opportunity for sign alignment and/or concurrent partner feedback was manipulated in a full factorial design. Each process made a distinct contribution to the evolution of shared symbols: sign alignment directly influenced communication success, and concurrent partner feedback drove sign simplification and symbolization. These complimentary processes led to the interactive evolution of effective and efficient human communication systems.

Keywords: Human Communication, Interaction, Icon, Symbol, Cultural Evolution, Language Evolution

Introduction

Human cognition and behaviour is dominated by symbol use, evident from our everyday use of numeric and linguistic systems. But where do these symbols come from? This question is presented by Harnad (1990) as the symbol grounding problem: how shared meanings can arise from arbitrary symbols in the absence of a pre-established shared symbol system. A solution to the symbol grounding problem was offered by Peirce (1931), who suggested that symbols evolved from iconic signs that share a non-arbitrary correspondence between the sign and its meaning.

This icon-to-symbol transition has been convincingly demonstrated in experimental-semiotic communication games. These experiments examine the creation of novel human communication systems under controlled laboratory conditions (for reviews see Fay, Ellison, & Garrod, 2014; Galantucci, 2017; Tamariz, 2017). They do this by using a paradigm in which human participants communicate without using their existing shared language. Typically, participants communicate in a novel modality, for example, through drawing (Galantucci, 2005; Garrod, Fay, Lee, Oberlander, & MacLeod, 2007; Healy, Swoboda, Umata, & King, 2007; Roberts, Lewandowski, & Galantucci, 2015) or by gesture (Christensen, Fusaroli, & Tylén, 2016; Fay, Arbib, & Garrod, 2013; Schouwstra & de Swart, 2014; Stolk, Verhagen, & Toni, 2016) and the experimenters examine how the communication systems arise and evolve over repeated interactions.

A key finding is the importance of iconic signs and social interaction to the creation of shared symbols (Galantucci, 2005; Garrod et al., 2007). In Garrod et al. (2007), pairs of participants tried to communicate a set of recurring meanings to their partner by drawing on a shared whiteboard. Like the game Pictionary, participants were not allowed to speak or use letters or numbers in their drawings. This procedure forced participants to create a novel communication system from scratch. Over repeated interactions three things happened: communication success improved, the signs used were transformed from complex iconic signs to simpler, more symbolic signs, and participants increasingly used the same signs to communicate the same meanings (i.e., their signs aligned; see **Figure 1**). This pattern, the creation of an effective inventory of shared symbols, has been widely replicated (Caldwell & Smith, 2012; Fay, Garrod, Roberts, & Swoboda, 2010; Garrod, Fay, Rogers, Walker, & Swoboda, 2010; Theisen, Oberlander, & Kirby, 2010).

These studies indicate that social interaction is crucial to the creation of effective and efficient human communication systems, but they are not clear on the precise mechanisms driving these outcomes. To better understand this, the present experiment isolates two important aspects of social interaction – behaviour alignment and concurrent partner feedback – and investigates the contribution of each to the evolution of shared symbols.

Pickering and Garrod (2004) argue that linguistic alignment drives successful communication. While there is a correlation between referential alignment and communication success (Fay, Lister, Ellison, & Goldin-Meadow, 2014; Fusaroli et al., 2012; Reitter & Moore, 2014), the causal role of referential alignment on communication success is unclear. If referential alignment directly influences communication success, then prohibiting interacting participants from aligning their signs will lower communication success.

Concurrent partner feedback can take a variety of forms. During conversation, listeners are co-narrators who provide verbal feedback (e.g., saying “mhm” while listening to a speaker) and visual feedback (e.g., frowning or nodding), that improves the flow of conversation (Bavelas, Coates, & Johnson, 2000; Clark & Krych, 2004; Mein, Fay, & Page, 2016). Like listeners in a conversation, participants engaged in an experimental-semiotic game can signal their attention and understanding by annotating their partner's sign, e.g., by adding a tick mark (see **Figure 1**). During conversation listeners can indicate a communication breakdown and initiate a repair (e.g., by asking the speaker for clarification; Dingemanse et al., 2015; Schegloff, 2000). In addition to these information expansion requests, listeners can drive information contraction by indicating their understanding (e.g., by saying "yeah, yeah"). So, concurrent partner feedback during an experimental-semiotic game may drive communication success and sign simplification/symbolization.

The present experiment examined the influence of sign alignment and concurrent partner feedback on communication success and sign symbolization. It also tested if each process operates independently or if they interact.

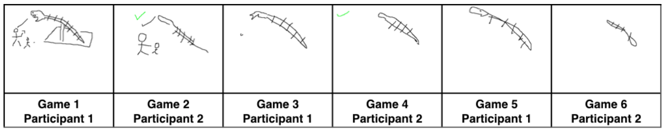

Figure 1. Sign simplification and alignment for the meaning 'Museum' across 6-games between a pair of participants in the present experiment. Participants alternated drawing and identifying roles from game to game. At Game 1 Museum was communicated using a complex iconic sign that included a dinosaur, an exhibit space and two viewers. By Game 6 the sign has lost much of its initial iconicity, evolving into a simpler, more symbolic representation, communicated by the dinosaur's spine. In addition, partners' signs became increasingly similar, or aligned, across games.

Method

The experiment received approval from the University of Western Australia Ethics Committee. All participants viewed an information sheet before giving written consent to take part in the study. The information sheet and consent form were both approved by the aforementioned Ethics Committee.

Participants

One-hundred and twenty undergraduate students (84 females) participated in exchange for course credit or payment. Participants were tested in unacquainted pairs in testing sessions lasting 1 hour. All participants were free of any uncorrected visual impairment.

Task and Procedure

Participant tried to graphically communicate a series of confusable meanings to their partner. Like the game Pictionary, participants were prohibited from speaking or using letters or numbers in their drawings. The Director would draw each meaning from their ordered list (16 targets plus 4 distractors; see **Table 1** for a complete listing) and their partner, the Matcher, would try to identify each meaning from their randomly ordered list of the same meanings.

The task was administered using a virtual whiteboard tool (Healy, Swoboda, & King, 2002), which recorded all drawing activity. Each participant sat at a computer terminal where drawing input and meaning selection was made via a standard mouse. For the Director, each to-be-communicated meaning was highlighted in white text on a dark background at the top of the interface. Holding down the left mouse button initiated drawing. Director drawing was restricted to black ink and Matcher drawing was restricted to green ink (to distinguish between participants). By clicking an erase button on the interface participants were able to erase parts of the drawing. All drawing and erasing activity was displayed simultaneously on the Director and Matcher's shared virtual whiteboards. When the matcher believed they had identified the director's intended meaning they clicked the relevant button at the top of their interface, where there was a list of buttons corresponding to the competing meanings. Meaning selection brought the current trial to an end and initiated the next trial. No time limit was imposed, and participants were given no explicit feedback with regard to their communication success. Participants communicated remotely across networked computers and were unaware of their partner's identity.

Table 1. The set of meanings that Directors communicated to Matchers (distractor meanings given in italic). Target and distractor meanings were fixed across conditions and throughout the experiment.

Places	**People**	**Entertain-ment**	**Objects**	**Abstract**
Art Gallery	Arnold Schwarzenegger	Cartoon	Computer Monitor	Homesick
Parliament	Brad Pitt	Drama	Microwave	Loud
Museum	*Hugh Grant*	*Sci-Fi*	*Refrigerator*	Poverty
Theatre	Russell Crowe	Soap Opera	Television	*Sadness*

The experiment examined the contribution of behaviour alignment and concurrent partner feedback to communication success and sign symbolization. Participants were randomly assigned to one of four conditions that represented a combination of the factors of interest: +Alignment +Feedback (N= 30, or 15 dyads), +Alignment -Feedback (N= 30, or 15 interacting), -Alignment +Feedback (N= 30, or 15 dyads) and -Alignment -Feedback (N= 30, or 15 dyads). In the -Alignment conditions participants were instructed not to copy their partner's drawings. They were told they would have to use a different sign to that used by their partner to communicate each meaning. In the -Feedback conditions Matchers were unable to provide within-trial feedback. Specifically, they were unable to draw while acting as the Matcher (this functionality was removed from the virtual whiteboard tool). In this condition the Director clicked a send button when they had finished their drawing. Once done the list of competing meanings became available for selection by the Matcher. Thus, Matchers were unable to interrupt the Director's communication and bring the trial to an end.

Results

Participants followed the instructions not to align their signs (manipulation check). Not being able to align their signs reduced communication success. By contrast, eliminating the opportunity for concurrent partner feedback did not directly affect communication success. Concurrent partner feedback affected sign simplification; when feedback was eliminated the signs produced were more complex. Sign alignment also affected sign simplification, but the effect was much weaker compared to the effect of concurrent partner feedback. See **Figure 2** for examples of sign alignment and simplification in the different conditions.

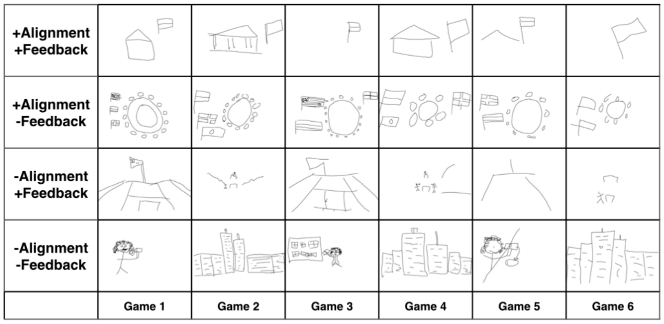

Figure 2. Sign alignment, simplification and symbolization for the meaning 'Parliament' across 6-games between participants in the different experimental conditions. Participants instructed not to copy their partner's sign for each meaning did so: one participant drew a building with a flag to communicate 'Parliament' and their partner drew a speaker at a podium (-Alignment +Feedback condition); another drew a parliamentary speaker with a hammer, and their partner drew a series of buildings (-Alignment -Feedback condition). When permitted to copy their partner's signs, sign alignment was observed: onto a flag (+Alignment +Feedback condition), or people seated around a table (+Alignment -Feedback condition). These examples highlight the diversity of signs used to communicate the same meaning in the present study. Concurrent partner feedback had a strong effect on sign simplification and symbolization: with feedback the signs were dramatically simplified across games (+Feedback conditions), and without feedback they retained considerable sign complexity (-Feedback conditions).

Manipulation Check: Sign Alignment

Participants in the -Alignment conditions were instructed not to copy the drawings produced by their partner. Sign alignment was quantified by rating the similarity of pairs of drawings of the same meaning from each pair (at Game 1-2, 2-3, 3-4, 4-5, 5-6) on a Likert scale from 0-9, where 0= very dissimilar and 9= very similar (BW). 4800 pairs of drawings were rated for similarity (16 meanings X 5 pairs of adjacent games X 15 pairs X 4 conditions). Sign alignment scores for the drawings produced in the different conditions are shown in **Figure 3**. The results indicate that participants followed the -Alignment instructions: those permitted to copy their partner's signs showed increasing sign alignment across games, whereas those not permitted to copy their partner's signs returned lower overall sign alignment scores that did not change across games.

Drawing alignment scores were entered into a mixed-design ANOVA that treated Alignment (+Alignment, -Alignment) and Feedback (+Feedback, -Feedback) as between-participant factors and Game (1-2, 2-3, 3-4, 4-5, 5-6) as a within-participant factor. This returned a statistically significant Alignment by Game interaction [$F_{Linear}(1,56)= 50.849$, $p< 0.001$, $\eta^2_p= 0.564$]. The interaction effect is explained by the increase in sign alignment scores across games in the +Alignment conditions [$F_{Linear}(1,29)= 131.622$, $p< 0.001$, $\eta^2_p= 0.819$] and a null effect of Game in the -Alignment conditions [$F_{Linear}(1,29)= 0.851$, $p= 0.364$]. The Alignment manipulation worked.

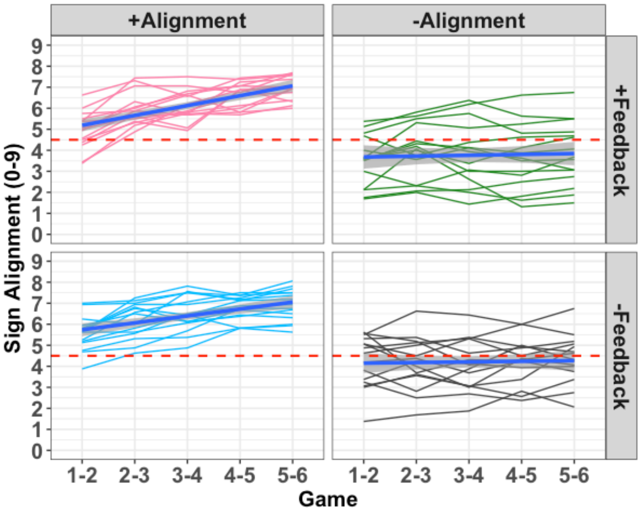

Figure 3. Change in sign alignment scores (plotted for each pair) for the different conditions across games 1-6. The horizontal dashed red line indicates neutral sign alignment. The dark blue straight line is the linear model fit and the light grey shaded area is the 95% confidence interval.

No outliers were identified using the Interquartile Range rule (Moore, McCabe, & Craig, 1993). Drawing alignment scores were entered into a mixed-design ANOVA that treated Alignment (+Alignment, -Alignment) and Feedback (+Feedback, -Feedback) as between-participant factors and Game (1-2, 2-3, 3-4, 4-5, 5-6) as a within-participant factor. This returned a statistically significant Alignment by Game interaction [$F_{Linear}(1,56)= 50.849$, $p< 0.001$, $\eta^2_p= 0.564$]. The interaction effect is explained by the strong increase in sign alignment scores across games in the +Alignment conditions [$F_{Linear}(1,29)= 131.622$, $p< 0.001$, $\eta^2_p= 0.819$] and a null effect of Game in the -Alignment conditions [$F_{Linear}(1,29)= 0.851$, $p= 0.364$].

The Alignment manipulation worked: participants who were allowed to copy their partner's drawings did so, and increasingly did so across games, whereas those who were prohibited from doing so did not copy their partner's drawings.

Communication Success

Communication success was operationalized as the percentage of meanings accurately identified by the Matcher. **Figure 4** shows the change in communication success (%) across games 1-6 in the different conditions. The results show an increase in communication success across games in all conditions, but the increase is stronger in the +Alignment conditions compared to the -Alignment conditions.

One outlier (0.28% of data) was identified using the Interquartile Range rule (see Moore et al., 1993). This value was replaced by next lowest value. The communication success scores were then entered into the same mixed-design ANOVA used previously. This returned a statistically significant Alignment by Game interaction [$F_{Linear}(1,56)= 135.151$, $p< 0.001$, $\eta^2_p= 0.707$]. In all conditions communication success improved across games: +Alignment conditions [$F_{Linear}(1,29)= 117.268$, $p< 0.001$, $\eta^2_p= 0.802$] and -Alignment conditions [$F_{Linear}(1,29)= 38.435$, $p< 0.001$, $\eta^2_p= 0.570$]. However, the improvement in communication success (differences score: game 6 - game 1) was stronger in the +Alignment conditions ($M= 24.17$, $SD= 12.031$) compared to the -Alignment conditions ($M= 13.96$, $SD= 13.993$), $t(58)= 3.030$, $p=0.004$, $d= 0.782$. The same pattern of results was returned when the communication success data was analyzed using logistic mixed effects modeling.

Sign alignment improved communication success, establishing a causal link between behaviour alignment and communication success. By contrast, concurrent partner feedback did not directly influence communication success [$p= 0.871$].

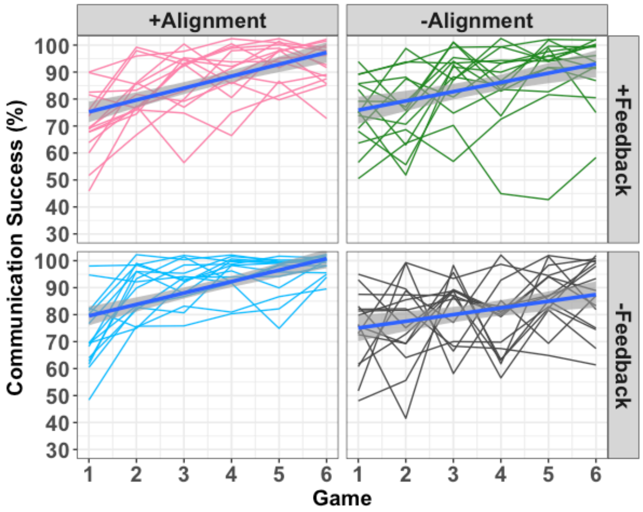

Figure 4. Change in communication success (plotted for each pair) for the different conditions across games 1-6. The dark blue straight line is the linear model fit and the light grey shaded area is the 95% confidence interval.

Sign Simplification and Symbolization

Following Garrod et al., (2007) simpler signs were considered to be more symbolic. Sign complexity was measured using Pelli et al.'s (2006) information theoretic measure of perimetric complexity [Perimetric complexity = (inside + outside perimeter)^2/ink area]. Previous work indicates this to be an effective scale-free measure of drawing complexity (Fay et al., 2010; Garrod et al., 2007; Tamariz & Kirby, 2014). Sign complexity scores for the drawings produced in the different conditions are shown in **Figure 5**. Sign complexity tended to decrease across games in all conditions, but sign complexity was lower in the +Feedback conditions compared to the -Feedback conditions.

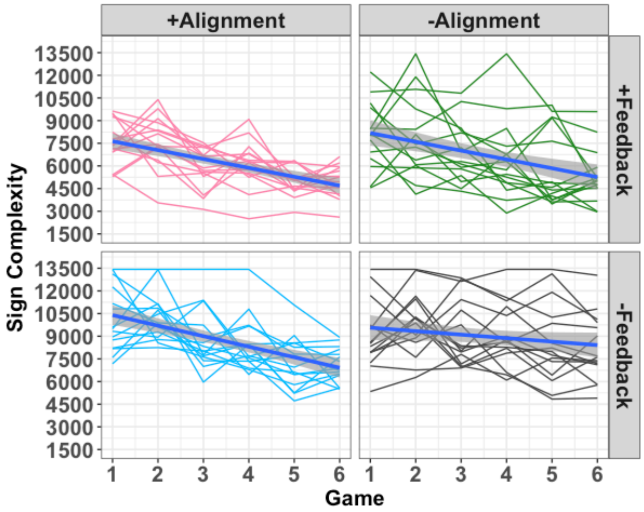

Figure 5. Change in sign complexity (plotted for each pair) for the different conditions across games 1-6. The dark blue straight line is the linear model fit and the light grey shaded area is the 95% confidence interval.

Ten outliers (2.78% of data) were identified using the Interquartile Range rule. These values were replaced by the next highest value. The sign complexity scores were then entered into the same mixed-design ANOVA used previously. This returned a statistically significant three-way Alignment by Feedback by Game interaction [$F_{Linear}(1,56)= 4.140$, $p= 0.047$, $\eta^2_p= 0.069$]. To understand the three-way interaction separate Alignment by Game ANOVAs were carried out for each level of Feedback. For the +Feedback conditions this returned a main effect of Game [$F_{Linear}(1,28)= 73.809$, $p< 0.001$, $\eta^2_p= 0.725$] with no other effects reaching statistical significance ($ps> 0.304$). So, both +Feedback conditions showed a similarly strong decrease in sign complexity scores across games, and there was no statistical evidence that sign alignment affected sign symbolization. A different pattern was returned by the -Feedback conditions. ANOVA returned a statistically significant Alignment by Game interaction [$F_{Linear}(1,28)= 6.608$, $p< 0.016$, $\eta^2_p= 0.191$]. This interaction effect is explained by the statistically significant decrease in sign complexity scores across games in the +Alignment -Feedback condition [$F_{Linear}(1,14)= 34.912$, $p< 0.016$, $\eta^2_p= 0.714$] and the null effect of Game in the -Alignment -Feedback condition [$F_{Linear}(1,14)= 2.825$, $p= 0.115$]. So, in the absence of concurrent partner feedback, sign alignment reduced sign complexity. Without either interactive process there was no statistical evidence of a reduction in sign complexity across games.

Receiving concurrent partner feedback was important to sign simplification and symbolization. In the absence of concurrent partner feedback sign alignment reduced sign complexity, but not to the extent of concurrent partner feedback.

Discussion

The present study investigated the precise role played by two distinct aspects of social interaction to the evolution of effective and efficient human communication systems: behaviour alignment and concurrent partner feedback. By experimentally manipulating the opportunity for behaviour alignment and concurrent partner feedback in a full factorial design, the experiment demonstrated that each process made a distinct contribution to the evolution of shared symbols: sign alignment directly influenced communication success and concurrent partner feedback drove sign simplification and symbolization. See Lister and Fay (in press) for a theoretical model of this process. Together, these complimentary processes explained the interactive evolution of effective and efficient human communication systems.

Our findings provide a solution the symbol grounding problem (Harnad, 1990). Complex iconic signs ground shared meanings. Once grounded, social interaction drives sign simplification and alignment, the mechanisms through which effective and efficient shared symbols arise. This explanation offers a convincing candidate process through which iconic signs evolve into symbols, as originally proposed by *Charles Sanders Peirce* over 100 years ago.

Other-initiated repairs are a frequent feature of conversation, and similar repair mechanisms are seen across a range of different languages (Dingemanse et al., 2015). Repairs – from a generic 'huh', to specific information requests – signal trouble and correct breakdowns in communication (Schegloff, 2000; Schegloff, Jefferson, & Sacks, 1977). Other-initiated repairs were a frequent feature of communication in the +Feedback conditions, especially in the early games of the task (25.83%, 17.92%, 13.75%, 11.25%, 7.91%, 2.91% of trials at Game 1-6). Yet, there was no evidence that this feedback directly affected communication success (19.16%-point improvement in communication success from game 1 to 6 with partner feedback, and a 19.95%-point improvement in communication success from game 1 to 6 without partner feedback (collapsed across the alignment conditions). By contrast, concurrent partner feedback was crucial to sign simplification and symbolization.

Why might other-initiated repairs not directly affect communication success? A simple answer is that people may not be sensitive to problems in communication in the first place. This was examined in a study in which conversation partners, who communicated via text-chat, were swapped with participants engaged in a separate and unrelated conversation (Galantucci & Roberts, 2014). Participants failed to notice their conversation partner had changed (beyond chance level), despite the incoherent change in topic. This finding suggests that communication is noisy and error-prone, and that people tend to be insensitive to communication problems. Perhaps our task is too simple to be able to detect the positive influence of other-initiated repairs on communication success. Against this, our experimental paradigm was sensitive to the positive influence of behaviour alignment on communication success.

Our experimental findings demonstrate that behaviour alignment directly influenced communication success. By contrast, there was no statistical evidence that other-initiated repairs directly affected communication success. This pattern of results supports models of dialogue that downplay the role of high-level cognitive processes, and stress the importance of behaviour alignment, via low-level processes such as priming, to successful communication (Garrod & Pickering, 2004; Pickering & Garrod, 2004). In the present study, although partner feedback did not directly affect communication success, it proved crucial to sign simplification and symbolization, which improved the smooth and efficient flow of communication (see also Bavelas et al., 2000; Mein et al., 2016).

Acknowledgments

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