Experimental semiotics

A new approach for studying the emergence and the evolution of human communication

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In the last forty years, students of human communication have developed a number of approaches for empirically investigating spoken dialogue (e.g., Garrod & Anderson, 1987; Goodwin, 2000; Horton & Keysar, 1996; Krauss & Weinheimer, 1964; Schegloff, Jefferson, & Sacks, 1977). These approaches, which may be collectively referred to as *experimental pragmatics* (Noveck & Sperber, 2006), have produced a wealth of knowledge about language use (e.g., Clark, 1996) and continue today to provide important insights into human communication (e.g., Brennan & Hanna, 2009; Garrod & Pickering, 2009; Shintel & Keysar, 2009).

This special issue focuses on a relatively new line of research on human communication which investigates the generalities of human semiosis rather than the specifics of spoken dialogue (Fay, Garrod, & Roberts, 2008; Galantucci, 2005; Garrod, Fay, Lee, Oberlander, & MacLeod, 2007; Healey, Swoboda, Umata, & King, 2007; Kirby, Cornish, & Smith, 2008; Selten & Warglien, 2007; Scott-Phillips, Kirby, & Ritchie, 2009). This line of research, which for convenience may be referred to as *experimental semiotics* (Galantucci, 2009), is similar to experimental pragmatics in at least two regards. First, both approaches aim at uncovering the causal relations behind the phenomena they observe by using methods that afford experimental manipulation and control. Secondly, they both share the assumption that, in order to understand human communication, researchers must investigate human social interactions as well as individual cognitive processes. Despite these similarities, however, experimental semiotics differs in a fundamental way from experimental pragmatics because it focuses on interactions that occur *in the absence* of pre-established communicative conventions. In other words, experimental semioticians study forms of communication which emerge de novo. To be sure, the emergence of novel forms of communication is not a new object of study. Researchers have

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extensively investigated both sign languages that emerge in relatively isolated populations (e.g., Kegl, Senghas, & Coppola, 1999; Sandler, Meir, Padden, & Aronoff, 2005) and home sign systems that emerge in families in which deaf children are raised by non-signing parents (e.g., Goldin-Meadow & Feldman, 1977; Goldin-Meadow & Mylander, 1998). However, because experimental semioticians observe the emergence of communication in the laboratory, they gain access to new opportunities for scientific inquiry. One of these opportunities is that of having access to the complete history of the development of a communication system. The details of this history can enhance our understanding of the processes that lead to successful communication. For example, three studies in experimental semiotics (Galantucci, 2005; Garrod et al., 2007; Healey et al., 2007) reported that signs established later on during the development of a novel communication system often incorporated parts of previously established signs. This occurred with communication systems which comprised only a handful of signs, suggesting the hypothesis that compositional structures may emerge in the very early stages of a communication system. Theisen, Oberlander and Kirby (this issue) tested this hypothesis directly and found supporting evidence for it (see also Galantucci, Kroos and Rhodes, this issue, for a related finding). Without the complete record of the history of a developing communication system, the hypothesis would have been difficult to test.

In addition, experimental semioticians can perform manipulations that would be difficult to realize outside the laboratory. For example, Fay and colleagues (Fay et al., 2008) systematically manipulated the composition of the communities of people in their study whereas Selten and Werglien (2007) manipulated the number of symbols that people could use to communicate with. Outside the laboratory, such manipulations would pose insurmountable ethical and practical challenges.

In the next section we introduce experimental semiotics in more detail, illustrating the main varieties of studies that contributed to its recent growth.

1. Experimental semiotics: Recent past of a growing discipline

In spite of its brief history, experimental semiotics has already grown in a few directions. In this section we survey the studies that contributed to this growth with the main goal of identifying the different lines of research that have emerged. In particular, we will focus on the methodological differences among these lines of research; readers that are interested in the specific results of the studies here surveyed are invited to refer to the original papers.

Referential semiotic games. The earliest studies in experimental semiotics were performed by Healey and colleagues (Healey, King, & Swoboda, 2004; Healey,

McCabe, & Katagiri, 2000; Healey, Swoboda, Umata, & Katagiri, 2002), who used a graphical medium to study the development of novel communicative conventions among pairs of individuals.[1] These researchers adopted standard referential communication tasks such as those used in experimental pragmatics (e.g., Krauss & Weinheimer, 1964) but prevented the use of spoken or written language. In particular, they asked people to graphically describe a stimulus such as a piece of music or a concept to a partner, without allowing them to use letters or numbers (we will refer to these tasks as *referential semiotic games*). The partner in the game was asked to recognize the stimulus among a set of stimuli in the case of concepts or, in the case of a piece of music, to say whether or not the description identified the same piece of music s/he heard for that trial. Over a number of rounds of the game, Healey and colleagues observed people developing spontaneous communicative conventions to succeed at the task. The development of such conventions has been extensively investigated in the last few years, through manipulations such as the type of interaction in the game (Garrod et al., 2007; Healey et al., 2007) or the social organization of the community of players that participated in the game (Fay et al., 2008). Despite slight differences in methods and research focus, studies performed with referential semiotic games all share the important feature that, whereas the set of forms that people use for communication is open, the set of referents to communicate in the game is typically closed and pre-determined by the experimenter. This choice is well suited for studying the emergence and evolution of signs but, as we shall see in a moment, it is not the only possible methodological choice in experimental semiotics.

Coordination semiotic games. A number of researchers (De Ruiter, Noordzij, Newman-Norlund, Hagoort, & Toni, 2007; Galantucci, 2005; Galantucci, Fowler, & Richardson, 2003; Scott-Phillips, Kirby, & Ritchie, 2009) have introduced tasks that involve more severe semiotic challenges than referential semiotic games by asking people to develop shared referents as well as shared communicative forms (we will refer to these tasks as *coordination semiotic games*). In other words, whereas referential semiotic games typically assign a set of pre-established referents to be communicated, coordination semiotic games leave players free to discover referents that support success in the game. Players of a coordination semiotic game move an agent in a virtual space with the overt goal of coordinating the moves with a partner (cf. Garrod & Anderson, 1987). Crucially, achieving the goal depends on successful communication. However, successful communication can be supported by different sets of referents and, in consequence, coordination semiotic games require players to converge on a common choice of referents as well on a common set of forms to indicate the referents. For example, in the game developed by Galantucci and colleagues (Galantucci, 2005; Galantucci et al., 2003)

coordination could be achieved either by referring to concrete spatial markers in the game environment or by referring to abstract geographic coordinates. In such conditions, converging on a shared set of referents is as important as developing forms to identify specific referents within the set. In fact, the semiotic challenge in coordination semiotic games is so severe that sometime participants perform very poorly or fail at the task (Galantucci, 2005; Scott-Phillips et al., 2009), providing useful information about the necessary ingredients for the emergence of communication (Galantucci, 2009; Galantucci & Steels, 2008).

Additionally, coordination semiotic games typically require players to communicate through fairly unusual means. For example, participants in the game developed by Galantucci and colleagues communicated through a graphical medium in which visual signals had a short permanence (similar to speech) and reflected only the horizontal component of the partiticipants' drawings. In such conditions, the possibility of using pictorial representations or well-established graphical symbols is greatly reduced (Galantucci, 2005). Other researchers (De Ruiter et al., 2007; Noordzij et al., 2009; Scott-Phillips et al., 2009) eliminated altogether the presence of a medium specifically dedicated to communication. In the coordination games developed by these researchers, players had to craft communication forms using the very actions that constituted moves in the games. In other words, participants in these studies had to find ways to signal that some of the moves that their agents performed had the intent of communicating rather than the intent of bringing the agent to a specific point in the game environment.

Referential linguistic games. The games surveyed so far are suited for studying the emergence and early evolution of communication systems but, because players often succeed at these games with relatively simple systems, they are not ideal for studying how sophisticated forms of language-like structures might emerge and evolve. For this purpose, a number of researches (Kirby et al., 2008; Roberts, 2008; Selten & Warglien, 2007) softened the semiotic challenge typical of referential games, providing players with a closed set of communication forms as well as a closed set of referents (we will refer to these tasks as *referential linguistic games*). In particular, Selten and Warglien (2007) provided pairs of participants with a set of letters which they had to combine to communicate about a closed set of geometric figures while Kirby and colleagues (Kirby et al., 2008) and Roberts (2008) asked people to memorize a pre-established mapping between artificial words and a closed set of referents. While they differ in terms of the social processes being studied—Selten and Warglien focused on dyads, Kirby and colleagues on chains of individuals, and Roberts on competing groups of players—these studies all share an important feature. Thanks to the use of closed sets of communication forms, it is possible to

create simple measures of language-like structures. In particular, the former two studies used these measures for detecting the emergence of compositionality, while the latter used them to study the emergence of subtle linguistic variations that distinguished different social groups.

In the next section we summarize the contribution of this special issue and illustrate how the different types of games introduced in this section have been utilized to investigate a number of related issues in experimental semiotics.

2. Summary of contributions in this issue

The contributions in this issue reflect the different methodologies used in previous work. The first two papers by Thiesen et al. and by Garrod, Fay, Rogers, Walker and Swoboda use referential semiotic games to investigate the circumstances under which different forms of sign emerge. Thiesen et al. consider two properties of the signs, what they call systematicity and arbitrariness. Systematicity is a property of composite signs in which an element of the sign recurs across different composite signs that refer to related concepts. For example, graphical signs relating to agricultural concepts (farmer, barn, tractor, field) might contain a common pictorial element representing a pitchfork. Arbitrariness relates to the extent to which a pictorial sign is not iconic (i.e., has no resemblance to its referent). Thiesen et al.'s experiments demonstrate that in graphical semiotic games these two properties are independent of each other. In particular, while the signs may show systematicity from the outset, it takes extended use for them to become arbitrary. This finding goes against the assumption that systematicity is only a property of arbitrary symbolic signs (see Deacon, 1997).

Garrod et al.'s study addresses a slightly different question about the circumstances in which pictorial signs become arbitrary or symbolic. Their previous work indicated that for pictorial signs to become arbitrary there needed to be graphical feedback between communicators (Garrod et al., 2007). In a further study they also demonstrated that both the simplification (and increased arbitrariness) of signs and convergence across communicators happened when sets of participants formed a closed communication network. More specifically, when groups of 8 participants communicated in successive pairs such that by the end of the experiment each member had communicated with each other, all members of a group converged on the same arbitrary sign for the same concept (Fay et al., 2008). The present paper tested whether this process of convergence on arbitrary signs might occur in multi-party transmission chains analogous to the iterated learning chains used in Kirby et al.'s (2008) experiments. The results indicated that, despite the occurrence of some convergence as the signs passed down the transmission chains (consistent

with predictions from iterated learning), there was no evidence that the signs became more arbitrary. This finding suggests interesting limitations on the evolution of increasingly arbitrary and symbolic signs. In particular it confirms the original claim (consistent with Peirce, 1931–58) that symbols evolve from what are originally iconic or indexical signs through a process of grounding which in turn depends on interactive feedback between communicators (Garrod et al., 2007).

The next two papers by De Ruiter et al. and Scott-Phillips investigate the early emergence of communication via coordination semiotic games in which players have no other means to communicate than the very moves of their agents in the environment.

Scott-Phillips argues that humans have a special capability to recognize the presence of communicative intentions. In particular he claims that, in contrast to other animals and artificial agents, humans can develop communication systems without necessarily relying on previously established behavioral patterns such as the unintentional release of information (cueing) or the automatic response to an external stimulus (coercion). In order to support his claim, Scott-Phillips first surveys the literature on communication among animals and among artificial agents and concludes that, in both cases, there is no indication that communication can emerge without the prior existence of cueing or coercive behaviors. Then Scott-Phillips contrasts this conclusion with the results of a coordination semiotic game that he developed with his colleagues (Scott-Phillips et al., 2009). In this game, pairs of participants must coordinate their moves but, as mentioned above, they have no other means to communicate other than the very moves of their agents in the environment. Moreover, the repertoire of movements in the game is highly constrained (agents could move only from the center of a room to the center of an adjacent room) and the game set-up prevents players from resorting to cueing or coercion. In such conditions, conveying communicative intents is challenging and complete failure is not uncommon. Yet, a number of pairs succeeded in developing a communication system, typically by using moving sequences that would have been unnecessarily complex as actual moves in the game environment. Considering the previous conclusion about the impossibility of such success for other animals or artificial agents, Scott-Phillips argues that the capacity that led humans to succeed in the game is unique to them.

De Ruiter et al. further investigate the processes through which humans develop communicative behaviors by studying the complementary emergence of behaviors that imply the intent to communicate to an audience (recipient design) and of behaviors that imply intention recognition. De Ruiter and colleagues used a coordination semiotic game in which a player had to perform two tasks simultaneously. The first task was that of moving and rotating an object on a grid in order to place it in a target location with a specific orientation. The second task was that

of using the moves on the board to communicate to the partner the target location and orientation for the object s/he controlled. Considering that the objects, the target locations, and the target orientations could all be different, the communicative challenge of the game was again not trivial. However, as in the study by Scott-Phillips et al. (2009), De Ruiter and colleagues found that people were able to perform the task successfully. De Ruiter and colleagues present two experiments in which they further investigated the processes that led to such success. The results of these experiments support three main conclusions. First, feedback is important for the emergence of successful communication, a result that confirms the conclusions of a number of referential semiotic games (e.g., Garrod et al., 2007; Healey et al., 2007). Second, the difficulty of a communicative act is reflected in the planning times of both players involved in it, indicating that the task involves both recipient design and intention recognition. Third, there is no trade-off between the planning time in senders and receivers, indicating that when communicative acts are difficult, the difficulty of intention recognition is not mitigated by sophisticated forms of recipient design (and vice versa). De Ruiter et al. argue that their results are indicative of the presence of a specialized communicative intelligence in humans and propose the game that they developed as a viable tool to further investigate the exact nature of such intelligence.

The paper by Galantucci et al. also used a coordination semiotic game but the primary focus of the paper was that of investigating the semiotic properties of the sign systems that emerged in the game, rather than the emergence of communication itself. Galantucci and colleagues manipulated the rapidity with which forms faded in the medium used by players to communicate in the game. The results of the experiment support two main conclusions. First, rapidity of fading does not affect the pace with which sign systems are developed nor does it affect the efficacy with which these systems support communication. In other words, rapidly fading forms afford the same opportunities for communication as forms that fade more slowly. However, rapidity of fading had a profound effect on the type of sign systems developed by the players. In particular, systems developed with forms that faded more rapidly re-used their forms in combination much more frequently than systems developed with forms that faded more slowly. Considering that speech rapidly fades in its natural medium, Galantucci and colleagues argue that this result suggests that one of the core design principles of spoken language, combinatoriality, may be influenced by a simple physical property of the medium in which speech is implemented.

The final two papers by Cornish and Roberts report experiments using linguistic referential games. Cornish begins by arguing that such games may give important insights into how individual learning processes can lead to emergent properties of sign systems as a consequence of inter-generational transmission. The paper

highlights the value of experimental manipulation. In two studies, she manipulates the information that can be transmitted across generations. Computer simulations using iterated learning have shown that transmission restrictions are crucial for the emergence of compositional languages. If a subsequent generation of learners is exposed to all or most of the previous generation's language then the language does not adapt in any interesting ways. If exposed to too little of the previous generation's language the language becomes unstable across generations. However, with just the right amount of transmission, compositional languages eventually emerge. So in her first illustrative experiment Cornish created human iterated learning chains either with or without such a transmission bottleneck. Surprisingly, for the human participants the presence of a transmission bottleneck had no effect on learnability of the artificial languages or the amount of structure they exhibited. Cornish concludes that for humans, unlike computer models, memory limitations may produce information bottlenecks. In other words, it is not the sparsity of the language input that is crucial for compositionality to emerge but the presence of any information bottleneck.

Cornish's second experiment addressed another difference between the results from the human iterated learning task and the simulations. As the languages passed down the human iterated learning chains, they became increasingly ambiguous, with the same expression taking on as many as nine different meanings. This was not possible in the computer simulations because they were limited to unique expression-meaning mappings. To make the situations comparable Cornish filtered the information transmitted along the human iterated learning chain such that only unique expression-meaning mappings were passed to the next generation. This had an interesting effect on the emergent languages, which was to increase the degree of structure and foster greater compositionality.

Roberts used a linguistic referential game to investigate how frequency of interaction and group conflict affect linguistic divergence in populations of interacting individuals. The effects of both factors have been observed in the field by sociolinguists and modeled with computer simulations. However, Roberts suggests that these approaches are not ideal for discriminating linguistic divergence due to frequency of interaction from divergence due to group conflict. On the one hand, frequency of interaction and group conflict often co-occur in the field; on the other hand, computer simulations can model the complex subtleties of human social relations only to a limited extent. Roberts presents an experimental study with humans in which the two factors have been manipulated independently. In particular, Roberts studied teams of players who used an artificial language in order to negotiate transactions in a game. The game rewarded generous transactions between pairs of team partners while punishing generous transactions between pairs of players of opposing teams. Pairs of players played the game in one

of four conditions. In the first two conditions the game was a competition between two teams of two players whose interactions with the team partner were either as frequent as interactions with the opponents or less frequent than interactions with the opponents. In the third and fourth condition the game was a fully cooperative task with four players whose interactions were either symmetric (each player played with every other player an equal number of times) or asymmetric (each player played more often with one of the partners). The main result of the study was that, with frequent interactions, players became able to identify one another on the bases of linguistic cues. However, this led to substantial linguistic divergence among players only in the competitive condition. Considering that the game lasted only a few tens of minutes, Roberts concludes that, when human interactions are both conflictive and frequent, linguistic divergence occurs at a very fast pace.

3. Future directions

As we have illustrated in the last two sections, experimental semioticians have begun to explore a number of factors that affect the emergence and evolution of human communication. Here we identify three main themes that emerge from such explorations which we believe can become major directions for future research in the field.

The first theme concerns the social interactions that support the emergence and evolution of communication systems. Previous studies in experimental semiotics demonstrated that rich forms of individual interactions are crucial for the development of sophisticated forms of communication (Garrod et al., 2007; Healey et al., 2007). Current studies investigate the differences between different kinds of communication networks (Cornish, this issue, Garrod et al., this issue, Roberts, this issue), going beyond the level of the dyad. Further research in this direction would be very helpful as natural communication systems typically originate from complex social networks which span over a large range of temporal and spatial scales (Loreto & Steels, 2007). Granted, studying larger communities of players for longer periods of time might prove to be a substantial challenge for experimental semioticians but the endeavor would be worthwhile, as it would provide invaluable insight into the phenomena that lead to language creation and language change (DeGraff, 1999).

The second theme concerns the linguistic structures that emerge in semiotic games. Previous studies demonstrated that players of semiotic games develop communication systems that often manifest fundamental linguistic properties (Galantucci, 2005; Garrod et al., 2007; Healey et al., 2007; Kirby et al., 2008; Selten & Warglien, 2007). Current studies further investigate this phenomenon, focusing on

properties such as systematicity, arbitrariness and combinatoriality (Galantucci et al., this issue; Theisen et al., this issue). Further research in this direction would be helpful as experimental semioticians might uncover fundamental design principles that are behind human natural communication systems. For example, experimental semioticians could provide further insight into the differences and similarities in design between speech and sign-language (Meier, Cormier, & Quinto-Pozos, 2002).

The third theme concerns the very emergence of communication. Previous studies demonstrated that humans seem to possess a strong talent for communicating in fairly challenging conditions (De Ruiter et al., 2007; Galantucci, 2005; Scott-Phillips et al., 2009). Current studies further investigate this phenomenon, focusing on the differences between humans on one side and animals and artificial agents on the other (Scott-Phillips, this issue) or on the behavioral and neural processes that support successful acts of communication (De Ruiter et al., this issue Noordzij et al., 2009). Further research in this direction would be helpful as it could provide new insights into the behavioral and neural pre-requisites of human communication (Arbib, 2006; King, 1999).

To conclude, we would like to propose two further issues which we believe should be high in the agenda of experimental semioticians to strengthen the scientific foundations of our common endeavor. First, it would be helpful to develop more explicit computational models of the phenomena we observe in our experiments. Such models would guide our research, providing specific predictions to be tested in our experiments. Second, it would be helpful to investigate the role played by pre-existing communicative expertise in our games. Semiotic games are typically played by proficient users of a number of well-established communication systems and this expertise can inform novel communication systems. The failures in establishing any form of communication in some semiotic games (Galantucci, 2005, 2009; Scott-Phillips et al., 2009) suggest that applying this expertise in the context of semiotic games is not a trivial matter. Nevertheless, it would be important to measure the extent to which successful players tap into their pre-existing communicative expertise. This can be done by testing the very semiotic games we use with human adults with agents that posses limited pre-existing communicative expertise such as pre-linguistic children, animals or artificial agents. These tests might prove to be a serious experimental challenge, but they would give a new and more powerful meaning to the term experimental semiotics.

Notes

1. A few years before the studies presented in this paragraph took place, Goldin-Meadow and colleagues (Goldin-Meadow, McNeill, & Singleton, 1996) studied the generation of novel

forms of human communication in the laboratory. In particular, they asked people to describe visually presented scenes twice, first using speech and then using exclusively gesturing. In a general sense, the latter condition qualifies as the first study in experimental semiotics. However, the messages produced by the gesturers in this study had no actual recipients, but for the experimenters who coded them. In other words, participants engaged in imagined rather than actual communication. For this reason, we opted for not including this study in the present survey.

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