Experimental Semiotics

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Abstract

In the last few years, researchers have begun to study novel human communication systems in the laboratory (*Experimental Semiotics, ES*). The first goal of this article is to provide a primer to ES, which we will do by reviewing the experimental paradigms developed by experimental semioticians, as well as the main research themes that have emerged in the discipline. A second goal is to illustrate what implications ES has for linguistics. In particular, we will argue that ES has the potential to complement linguistics in important ways and illustrate such potential in the context of each of the themes we review.

> "It is therefore possible to conceive of a science *which studies the role of signs as part of social life*. It would form part of social psychology, and hence of general psychology. We shall call it *semiology* (from the Greek *semeîon*, 'sign'). It would investigate the nature of signs and the laws governing them. Since it does not yet exist, one cannot say for certain that it will exist. But it has a right to exist, a place ready for it in advance. Linguistics is only one branch of this general science. The laws which semiology will discover will be laws applicable in linguistics, and linguistics will thus be assigned to a clearly defined place in the field of human knowledge."
>
> (de Saussure 1916/1998: 15-16, italics in the original).

> "If one wishes to discover the true nature of language systems, one must first consider what they have in common with all other systems of the same kind. Linguistic factors which at first seem central (for example, the workings of the vocal apparatus) must be relegated to a place of secondary importance if it is found that they merely differentiate languages from other such systems. In this way, light will be thrown not only upon the linguistic problem."
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> (de Saussure 1916/1998: 17).

1. Experimental Semiotics and its broad implications for linguistics

In the last few years, a science has emerged that is very much in the spirit of that envisioned by de Saussure in the first quote above. Researchers who are developing this science, which has been labeled *Experimental Semiotics* (Galantucci 2009; Galantucci and Garrod 2011), conduct controlled studies in which human adults develop novel communication systems (e.g., de Ruiter et al. 2010; Galantucci 2005; Garrod et al. 2007; Healey et al. 2007; Scott-Phillips et al. 2009) or impose novel structure on systems provided to them (Kirby et al. 2008; Roberts 2010; Selten and Warglien 2007).

This article has two main goals. The first is that of providing a primer to Experimental Semiotics (henceforth *ES*). In particular, we review the experimental paradigms developed by experimental semioticians as well as the main research themes which have emerged in ES. The second goal is that of illustrating the implications ES has for linguistics. In the remaining part of this introduction we illustrate the broadest of such implications. Other implications will be illustrated in connection with the themes we review.

Since novel forms of communication can emerge relatively rapidly in the laboratory (Galantucci 2005), ES provides an opportunity to study a wide variety of communication systems. As intuited by de Saussure in the second quote above, this is an important opportunity because it enables one to investigate human language[1] in very general terms, distinguishing its core mechanisms from the idiosyncrasies of any specific communication system. Thus far de Saussure's intuition has had limited recognition and implementation in linguistics. In fact, the core of modern linguistics has been developed under two related assumptions, which we will here refer to collectively as the *speech assumptions*. The first assumption is that speech has a central place among human communication systems and that studying it can provide us with all we need to understand language. The second assumption is that speech can be fully understood *from within itself*, that is, without studying it in a comparative fashion with respect to other human communication systems. The speech assumptions seem rather reasonable. Speech and the many writing systems derived from it are by far the most common communication systems used by humans; other systems are either much less common (e.g., sign language) or much less powerful (e.g., road signs). Perhaps for these reasons, the speech assumptions are so ingrained in modern linguistics that two well-known and insightful linguists, when they attempted to define the essence of human language, included the use of the vocal-auditory channel as a feature (Hockett 1960; Martinet 1984).

An important opportunity to challenge the speech assumptions arose about half a century ago, when researchers began to investigate languages which are not implemented over the vocal-auditory channel, in particular signed languages. However, the opportunity was not readily exploited. In order to persuade the linguistic community that they were indeed studying fully-fledged languages, students of sign language highlighted the similarities between spoken and signed languages rather than the differences (Stokoe 1960). Thus, the study of sign language coexisted for about four decades with the speech assumptions and it was not until very recently that sign language researchers have begun to overtly challenge them (Vermeerbergen 2006).

This challenge has direct implications for students of speech. For example, arbitrariness has long been considered one of language's defining features (de Saussure 1916/1998; Hockett 1960). However, spoken language is not entirely arbitrary (e.g., Haiman 1985; Hinton et al. 1994), suggesting that perhaps arbitrariness is not a *critical* feature of human language. Students of sign language recently provided support for this hypothesis, demonstrating not only that spontaneously emerged sign languages have deep and vast iconic roots (Fusellier-Souza 2006) but also that a fairly high degree of iconicity remains one of the defining features of more established sign languages (Aronoff et al. 2008; Demey et al. 2008; Taub 2001). In this light, the relatively high level of arbitrariness found in speech may be considered a by-product of the vocal-auditory channel rather than a critical feature of language. As we shall see below, ES studies provide further support for this hypothesis.

More generally, ES can provide an important complement to research with natural languages, for three reasons. First, experimental semioticians can study a much greater variety of communication systems than those that already exist in the world. Indeed, as long as humans can reliably detect and produce signals in the virtual environment created by experimental semioticians, any means of communication can be explored in the laboratory. For instance, a number of experimental semioticians (de Ruiter et al. 2007; Galantucci 2005; Scott-Phillips et al. 2009) observed people creating communication systems in media which had never been used before for human communication (see 2.1.2).

Second, experimental semioticians have access to the *full history* of the development of a novel communication system and, as we shall see in Section 2.2, this is an important opportunity for thoroughly understanding some of the system's features. Outside of the laboratory such an opportunity does not exist (but see Roy et al. 2006 for an interesting exception concerning language acquisition).

Third, experimental semioticians can readily manipulate the circumstances under which novel communication systems develop. For example, Galantucci and colleagues (Galantucci et al. 2010) manipulated the rate of fading of the forms people used to communicate, and a number of experimental semioticians manipulated the type of interaction which took place within the communities they were studying (Fay et al. 2008; Garrod et al. 2010; Healey et al. 2007; Roberts 2010). Outside of the laboratory such manipulations would be impractical or unethical.

Before discussing further the implications ES has for linguistics, let us have a closer look at it.

2. Experimental paradigms and research themes in ES

In what follows, we introduce the main paradigms developed by experimental semioticians and then describe five research themes which have emerged within ES.

2.1. EXPERIMENTAL PARADIGMS

In spite of its very recent origins, ES has already developed a number of experimental paradigms.

2.1.1. Semiotic Referential Games

Some experimental semioticians use a referential communication task. In the standard version of this task, people converse about novel shapes using natural language (Krauss and Weinheimer 1964); in the ES version, the use of natural language is proscribed (Fay et al. 2008, 2010; Garrod et al. 2007, 2010; Healey et al. 2002, 2007; Theisen et al. 2010). In particular, people repeatedly draw a stimulus such as a piece of music or a concept for a partner to identify, but are proscribed from using letters or numbers (henceforth *Semiotic Referential Games*). Over a number of trials, dyads or small communities of players develop spontaneous communicative conventions to succeed at the task. Studies performed with Semiotic Referential Games all share the important feature that, whereas the set of forms that people use for communication is open (i.e., they can draw what they like) the set of referents to communicate in the game (e.g., concepts or pieces of music) is closed and pre-determined by the experimenter. Because of this, Semiotic Referential Games are particularly well suited to studying the early evolution of sign systems.

2.1.2. Semiotic Coordination Games

Some experimental semioticians (de Ruiter et al. 2010, 2007; Galantucci 2005; Galantucci et al. 2010; Scott-Phillips et al. 2009) use tasks in which people move an agent in a virtual space with the goal of coordinating the moves with a partner (henceforth *Semiotic Coordination Games*). As in Semiotic Referential Games, achieving the goal requires players to develop novel communication systems. However, there are two differences between Semiotic Coordination Games and Semiotic Referential Games. First, in Semiotic Coordination Games successful communication can be supported by different sets of referents and, in consequence, these games require players to converge on a common

choice of referents as well as on a common set of forms to indicate the referents. This makes the task considerably more challenging and sometimes players completely fail (Galantucci 2005; Scott-Phillips et al. 2009). The second difference is that in Semiotic Coordination Games players do not communicate through drawings but through fairly unusual means. Participants in the game used by Galantucci and colleagues (Galantucci 2005; Galantucci et al. 2003; Galantucci et al. 2010) communicated through a graphical medium in which visual signals had a short permanence (similar to speech) and reflected only the horizontal component of the participants' drawings (see Figure 1A). This signal not only prevented the use of letters or numbers but also reduced the possibility of using pictorial representations (Figure 1B). Other researchers (de Ruiter et al. 2007; 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. Because of these differences, Semiotic Coordination Games are well suited to studying the basic processes which support the bootstrapping of communication.

2.1.3. Semiotic Matching Games

Finally, some experimental semioticians (Cornish 2010; Kirby et al. 2008; Roberts 2008, 2010; Selten and Warglien 2007) provide players with a closed set of communication forms and a closed set of referents. These are either matched in advance by the experimenter or must be matched by the players during the game (henceforth *Semiotic Matching Games*). Studies involving semiotic matching games are fairly heterogeneous. While Selten and Warglien (2007) focused on communication in dyads, Kirby et al. (2008) and Cornish (2010) focused on language transmission in chains of individuals, with no direct communication between these individuals. Roberts (2008, 2010), by contrast, focused on communication among groups of players with different goals. Despite these differences, researchers who use Semiotic Matching Games all benefit from the fact that, thanks to

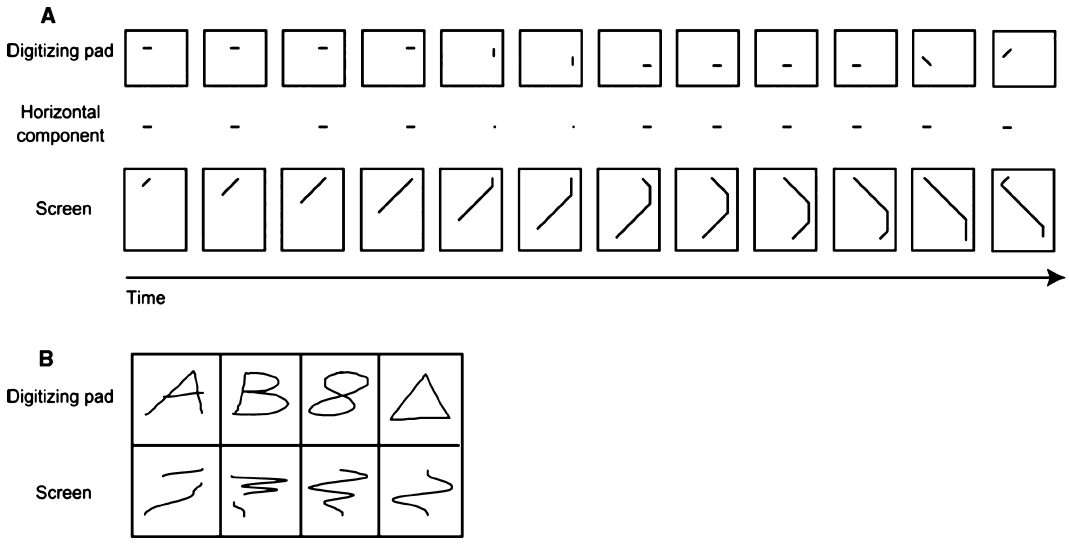


Fig 1. (A) How the drawings a player produced on the digitizing pad appeared on the screen (for both players). (B) How common graphic symbols drawn on the digitizing pad appeared on the screen. (Adapted from Galantucci et al. 2010.)

the use of closed sets of forms and referents, they can study language-like structures more systematically than researchers who use the two paradigms presented above.

2.2. RESEARCH THEMES

Five main themes of research emerged in ES thus far. They concern the emergence of linguistic structure, the role of interaction in communication, the role of inter- and intra-generational processes in the evolution of language, the study of sociolinguistic processes in the laboratory, and the bootstrapping of communication. In reviewing each theme, we highlight its implications for linguistics.

2.2.1. Emergence of linguistic structure

Experimental semioticians have demonstrated that the communication systems which they observe in their studies exhibit two important linguistic properties: combinatoriality and compositionality. These properties are important because, together, they are sufficient conditions for a defining feature of human language: duality of patterning (Hockett 1960; Martinet 1960).

2.2.1.1. Emergence of combinatoriality. Using a Semiotic Coordination Game, Galantucci et al. (2010) found that novel communication systems can exhibit a considerable degree of combinatoriality from their early inception. They analyzed 14 communication systems developed by different pairs (comprising on average about nine signs) and measured the combinatoriality of these systems by counting the number of times basic forms recurred across the signs of each system (for the details of the method, see Galantucci et al. 2010). The result was clear: across the 14 systems, basic forms recurred very frequently, suggesting that novel communication systems quickly adopt a combinatorial design. Interestingly, communication systems developed over a rapidly fading medium were more combinatorial than systems developed over a medium that faded more slowly (Figure 2). In other words, by manipulating rate of fading, Galantucci et al. uncovered one of its hidden effects. Considering that human natural languages typically rely on rapidly fading forms (e.g., patterns of sound or dynamic gestures), the study by Galantucci et al. suggests a new explanation for their high degree of combinatoriality, providing an example of how ES can lead to novel insights into the design of human communication systems.

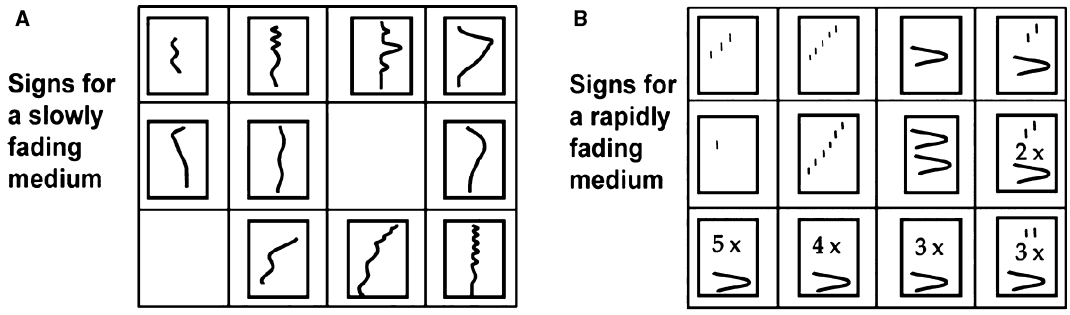


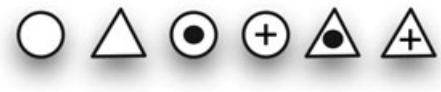
Fig 2. Examples of the sign systems studied by Galantucci et al. (2010). The signs are placed in the location on the game map they indicated. (A) Non combinatorial system. Each sign is composed of a distinct basic form. (B) Highly combinatorial system developed for the rapidly fading medium. Every sign contains at least one basic form that is present in one other sign. Forms are sequenced in time (numerals indicate how many times the same form was repeated).

2.2.1.2. Emergence of compositionality. One of the defining characteristics of the semantics of natural language is compositionality, by which complex expressions take their meaning from the combined meanings of their parts. Is there evidence for the emergence of compositionality during the evolution of communication systems in ES studies?

One of the first studies showing such emergence was by Selten and Warglien (2007). Pairs of participants played a semiotic matching game in which they had to match strings of letters to visual tokens (different shapes of different colors containing different inserts) in such a way that both players only succeeded if they made the same assignments (Figure 3 top row).

Over the course of many trials players came to develop common code systems, with the same mappings between the strings and the visual tokens. The question is whether these code systems exhibited compositionality. Selten and Warglien (2007) propose that such a code might look like that in Figure 3 (bottom row), in which the letter sequences R, RM and RZ are matched with figures such that R stands for circle, M for • insert and Z for + insert. Interestingly, although some players did develop compositional code systems and were especially successful with them, such systems only emerged when there was a wide range of different letters to use with a large number of visual tokens (i.e., when players had to encode novel meanings often).

Other studies also suggest that the emergence of compositional code systems depends on the task context. Kirby et al. (2008) used an iterated learning paradigm to investigate how non-linguistic code systems might evolve when passed down generations of learners (for an overview of this line of research, see Cornish 2010). In their task Player 1 learns an ''alien'' language made up of random pairings of written symbols (sequences of letters) with visual stimuli (colored objects in motion) and is then tested on both previously encountered and new symbols (i.e., combinations not previously seen) and the results of this test then become the learning set for Player 2. Player 2 then learns Player 1's version of the ''alien'' language, which is then passed on to Player 3 in the same fashion. This process iterates through a chain of 10 players. As with other iterated learning tasks, the languages changed as they were passed down the chain. But the nature of the resulting languages depended on what could be transmitted from player to player. If there was no



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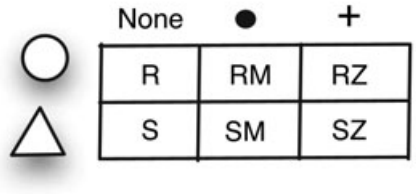

A compositional grammar

Fig 3. (Top row) Example of six visual tokens made up of two shapes and three inserts. (Bottom row) Example of a compositional grammer in which R signifies circle, S signifies triangle, M signifies • and Z signifies +. (Adapted from Selten and Warglien 2007).

interference in what was transmitted, chains settled on very ambiguous languages without compositionality. However, if at each transition all but one ambiguous word were removed from the learning set (leaving only unambiguous words), then more expressive languages emerged which commonly exhibited compositionality (see Figure 4).

The emergence of compositionality has also been demonstrated using a Semiotic Referential Game. Theisen et al. (2010) used a version of Garrod et al.'s (2007) *Pictionary* task to investigate compositionality. Crucially, they manipulated the semantic structure of the sets of concepts to be communicated. For example, they included different agricultural concepts (farmer, barn, farming, tractor) and a cross-cutting set of educational concepts (teacher, school, teaching, school bus). And, it turned out that their participants developed graphical signs exhibiting compositionality. For example, all signs relating to school concepts might include a 'chair' emblem (see Figure 5). Interestingly, many of the emblems bore an iconic relation to the concepts they represented.

2.2.2. Implications of this theme for linguistics

The fact that both compositionality and combinatoriality can be found in communication systems developed in ES studies suggests that these systems, albeit much simpler and smaller than natural languages, exhibit similar properties to natural languages. Studying such systems in the laboratory may offer new insights for linguists. For example, Theisen et al. (2010) demonstrated that non-arbitrary signs exhibit compositionality, suggesting that Deacon's hypothesis that true compositionality implies arbitrariness might be incorrect (Deacon 1997: 99). In fact, Theisen et al. found that the development of compositionality and the development of simplification (an indicator of increasing arbitrariness) were quite independent of each other in the context of the Pictionary task. ES offers other insights concerning arbitrariness. High levels of iconicity are commonly found in studies which

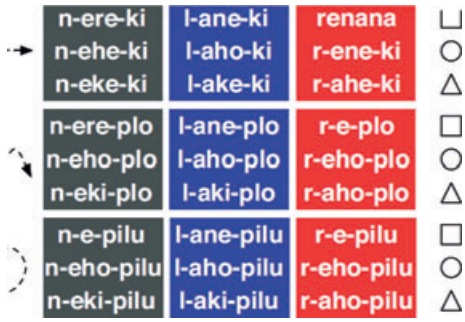

Fig 4. Example of a partially compositional grammar elicited by Kirby et al. (2008) iterated learning task. The string associated with a picture consists of substrings expressing color (n,l,r), shape (ere, eho, eki) and motion (ki, plo, pilu) respectively. The hyphens were added for clarification and were not present in the words produced by the original participants. (From Kirby et al. 2008).

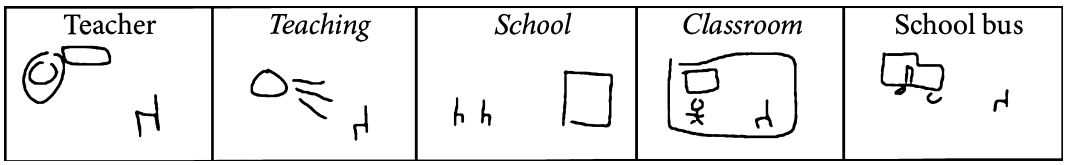

Fig 5. Example of drawings elicited by Theisen et al.'s (2010) experiment that illustrate partial compositionality. All educational concepts include a small chair token (Adapted from Theisen et al. 2010).

use the Pictionary task (e.g., Fay et al. 2010; Garrod et al. 2007; Theisen et al. 2010) and, as we will see in the next section, Fay et al. (2008) explained why evolving communication systems may retain part of their iconic roots. In other words, ES studies are consistent with the aforementioned suggestions from the study of signed languages: A high level of arbitrariness is not an essential feature of language and may be a consequence of the vocal-auditory channel. Other features of spoken language might be consequences of adaptations specific to speech as well. For example, the study by Selten and Warglien (2007) mentioned above showed that the emergence of communicative conventions is facilitated by inventories of signal units that are relatively large with respect to the number of meanings that people express by using the units. The fact that full-blown languages that express thousands of meanings can rely on inventories composed of as few as eleven phonemes (Firchow and Firchow 1969) might again be the consequence of specific adaptations for the audio-vocal channel. Indeed, signed languages rely on inventories which are at least an order of magnitude larger (Liddell and Johnson 1989).

2.2.3. The role of interaction in human communication

Researchers who use Semiotic Referential Games have investigated the role of social interaction in the early evolution of signs (Garrod et al. 2007; Healey et al. 2007). Healey et al. (2007) had participants communicate about snippets of music by drawing on a shared whiteboard which could or could not be used simultaneously by the players. Drawings in the former condition were more abstract than in the latter, which the authors explained in terms of the more tightly coupled production and feedback in the simultaneous-drawing condition. Similarly, Garrod et al. (2007) had pairs of participants communicate a series of easily confusable items (e.g., Microwave, television, computer monitor) by drawing on a whiteboard and manipulated whether participants were allowed to interact graphically. With even a very minimal level of graphical interaction (e.g., a tick to indicate comprehension), partners' drawings converged and developed from iconic to arbitrary signs, a tendency which was more pronounced when players alternated roles in drawing and guessing (Figure 6). Without such interaction, drawings

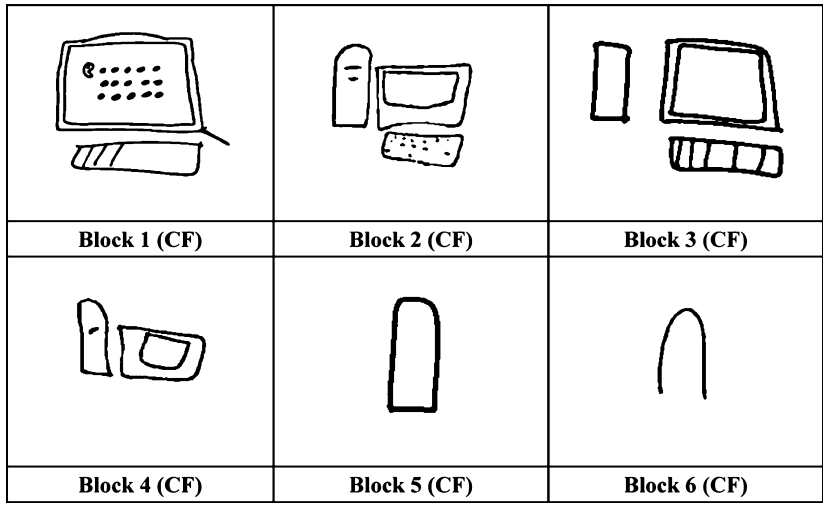

Fig 6. Drawing refinement and convergence for the concept 'Computer monitor' across six games between a pair of interlocutors playing the interactive version of the Pictionary task (From Garrod et al. 2007).

remained iconic and even became more complex. The authors argued that interaction promotes a shift in the locus of information from the sign to the users' memory, allowing the signs to become simpler as happens in more traditional experiments with spoken language (Clark 1995).

2.2.4. Implications of this theme for linguistics

The importance of interaction for the development of simplified arbitrary graphical signs is very much in line with findings from referential communication tasks using language (Clark and Wilkes-Gibbs 1986; Krauss and Weinheimer 1964). Other findings, such as the difficulty 'overseers' experience in identifying graphical signs developed through interaction (Garrod et al. 2007), also agree with the finding that 'overhearers' have problems interpreting linguistic descriptions of tangram figures developed during the course of linguistic interactions (Schober and Clark 1989). So the ES findings clearly indicate that the development of specialized and somewhat arbitrary descriptions (e.g., *ice skater* for an abstract tangram figure) is a feature of interactive communication (with any system of signs) rather than a special feature of linguistic communication as such.

2.2.5. Intergenerational transmission versus intragenerational communication

Experimental semioticians have investigated language transmission from individual to individual. Both ''vertical'' cross-generational transmission (e.g., Cornish 2010; Kirby et al. 2008), and ''horizontal'' coordination within communities (e.g., Fay et al. 2008, 2010; Healey et al. 2007) have been shown to lead to the emergence of compositionality, but only horizontal interaction has been shown to lead to systematic simplification of signs. Garrod et al. (2010) compared vertical and horizontal transmission directly. In one condition a pair of participants repeatedly communicated a set of concepts graphically and did so interactively. In a matched condition, the first drawing from the pair was used to seed an iterated-learning chain analogous to those in Kirby et al. (2008). In the horizontal, but not the vertical, condition, drawings became simplified (Figure 7).

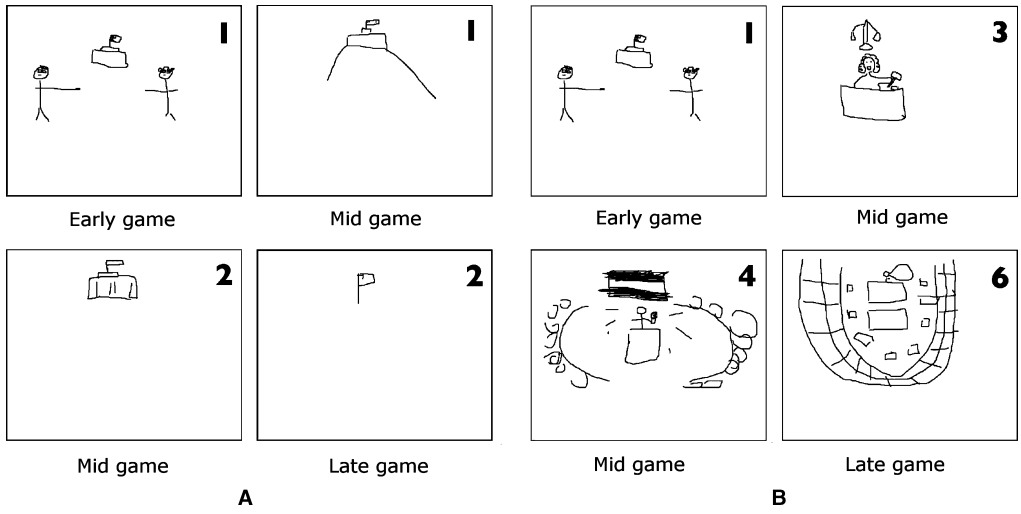

Fig 7. Drawings from interacting pairs (a) and iterated learning chains (b) from Garrod et al. (2010).The numbers identify distinct players.

Dyadic communication tasks also differ from iterated chains in the number of participants involved. To extend the graphical communication paradigm Fay et al. (2010) created four 8-person laboratory communities in which every participant played six consecutive games with every other member of a pool. This condition was contrasted with an Isolated Pair condition, in which participants interacted with the same partner over the same number of games. Isolated pairs converged on different simplified drawings, while a community would converge on a single simplified (and symbolic) representation (Figure 8). Fay, Garrod, and Roberts (2008) found, moreover, that community-generated drawings could be matched more accurately and quickly with their associated concepts than those produced by isolated pairs, suggesting that communities evolve signs which had lower degrees of arbitrariness and were more effective.

2.2.6. Implications of this theme for linguistics

Traditionally linguistic evolution has been thought of in terms of vertical transmission across generations of learners acquiring the language (Kirby and Hurford 2002). In particular, it has been proposed that a linguistic bottleneck (associated with constraints on learning) is the source of linguistic structure during evolution of language. In contrast, ES studies with the Pictionary task have highlighted the importance of horizontal coordination in driving language change. Such horizontal forces reflect the communicative effectiveness of the language in contrast to its learnability and would apply within generations of communicators as occurs in other areas of cultural evolution (Richerson and Boyd 2005). This means that languages could change at a much more rapid rate than suggested by vertical transmission processes alone.

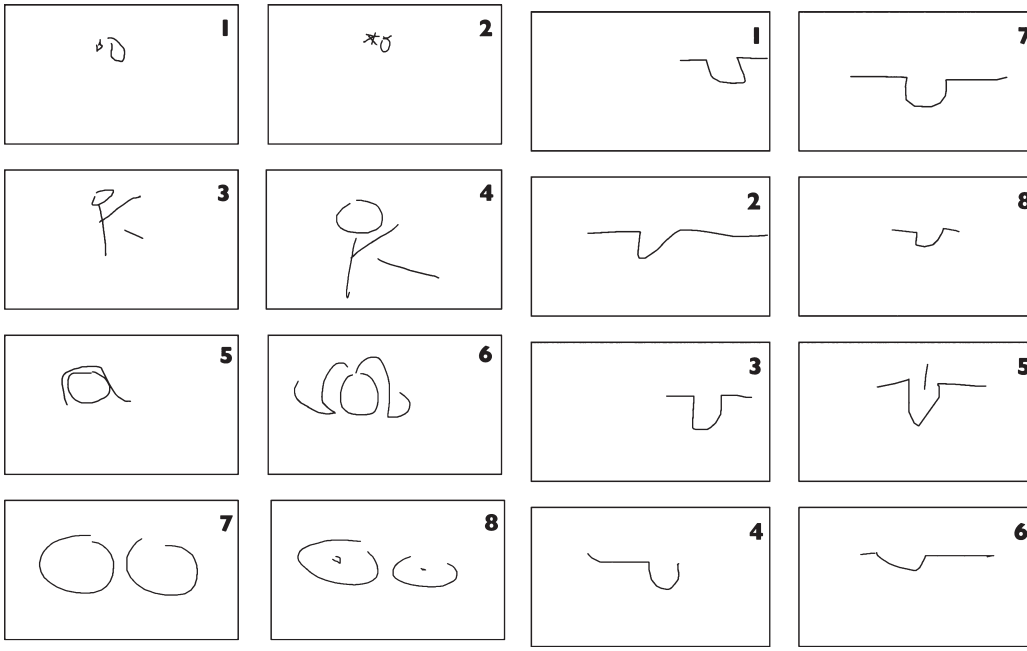

Fig 8. Shows different interacting pairs final drawings of 'Brad Pitt' (left) compared with one community's final drawings of 'Brad Pitt' (right).

2.2.7. Sociolinguistics in the laboratory

Inter-community social interaction exercises a different influence from within-community interaction. Roberts (2010) had groups of four participants use an initially uniform artificial language to negotiate transactions anonymously. He manipulated two social factors that have been argued to explain new-dialect formation: frequency of interaction between particular pairs of individuals (cf. Livingstone, 2002; Livingstone & Fyfe, 1999; Trudgill, 2004, 2008) and the presence of competing teams, which created a pressure to mark identity (cf. Labov, 1972; Nettle & Dunbar, 1997). Given sufficiently frequent within-team interaction, the competitive condition caused the artificial language to diverge into dialects, suggesting that the presence of competing groups can significantly increase the rate of language change.

2.2.8. Implications of this theme for linguistics

The science that Saussure envisaged would ''study the role of signs as part of social life''. Since the 1960s in particular (e.g. Hymes, 1964; Labov, 1963), sociolinguists have been studying language in precisely that way, studying it in its natural context. ES, by contrast, involves artificiality: researchers employ artificial languages (e.g. Kirby et al. 2008; Roberts 2010) or artificially constrain participants' communicative options (e.g. Galantucci 2005; Scott-Phillips et al. 2009). However, this artificiality produces natural communicative behavior (Galantucci and Roberts 2012), and ES studies can complement traditional sociolinguistic research in several ways, which are illustrated in Roberts (2010) study. By artificially manipulating frequency of interaction and competitiveness, he was able to keep distinct two factors that are typically entangled in existing communities and thus identify the causal relationship between these factors and the formation of new dialects. By introducing an artificial language to participants at the start of the experiment, he had full control over its initial state. This fact, taken together with the role the participants' imperfect memories played as a source of rapid mutation in the language, meant that he was able – in a couple of hours – to fully record the moment of birth of a new dialect. Outside the laboratory, observing the birth of a new dialect would require a researcher to be in the right place at the right time and to record large numbers of speakers over long periods. Furthermore, the lack of experimental control would make accurately identifying causal relationships impossible.

2.2.9. The bootstrapping of communication

Studies conducted with Semiotic Coordination Games have provided a few insights into the processes which lead to the successful bootstrapping of communication system without the aid of a previous one (de Ruiter et al. 2010; Galantucci 2005; Scott-Phillips et al. 2009).

2.2.9.1. Insights from successes. A study by Galantucci (2005) provided two such insights. First, the mechanism that supports the bootstrapping of a new communication system is similar to the mechanism of interactive output-input alignment described by Garrod and colleagues in the context of conversations using natural language (Garrod and Anderson 1987; Garrod and Pickering 2004). Second, in order to achieve coordination, people do not depend exclusively on the use of communicative signs, even when all the necessary signs are available. When the circumstances of the game allowed it, coordination was achieved by integrating the information provided by publicly broadcasted signs with other kinds of task-relevant information. For example, when the game environment comprised only three possible longitudes and players discovered through the use of signs that their

agents were at the same latitude, they rarely used further signs to coordinate their moves. Since their goal was that of bringing the agents in the same game location, they simply moved toward the central longitude. (If an agent was already in the central location, the player would not move it.) In other words, the behavior of the players reflected the efficient integration of (a) information contained in the signs (obtained through the communication medium and explicitly shared by the players), (b) information about the current location of the controlled agent (obtained privately and not shared by the players), and (c) information about the environment layout (obtained privately and implicitly shared by the players). Such integration is typical of natural language use (Clark 2005; Goodwin 2000; Tanenhaus et al. 1995).

Using a different Semiotic Coordination Game, in which players moved agents around a simple multicolored grid with the goal of ending up on the same color, Scott-Phillips et al. (2009) provided insights into the processes through which actions assume a communicative value. These processes were typically composed of two steps. The first step was to establish a salient default coordination procedure, which consisted of a shared decision bias for the ''right'' game behavior to perform (e.g., always choosing the red color if available; cf. Schelling 1960). The second step occurred when the default coordination procedure was not viable. This was typically signaled by performing a series of behaviors which would have been unnecessarily complex had the default coordination procedure been available. The unexpectedness of these behaviors prompted the partner to recognize a communicative intent and, over time, these behaviors came to signify new coordination procedures, enriching the communicative repertoire of the pairs. Scott-Phillips and colleagues demonstrated the fundamental importance of the first step via a simple manipulation. When default coordination procedures were made more difficult to establish, failures in the game occurred about twice as frequently.

de Ruiter et al. (2010) provided further insights into the complementary emergence of behaviors that imply the intent to communicate to an audience (recipient design) and of behaviors that imply intention recognition. The results of their study support three main conclusions. First, feedback is important for the emergence of successful communication, confirming the conclusions of the studies reported in Section 2.2.3. The other two conclusions concern the time it took players to plan their behaviors in the game. In particular, de Ruiter and colleagues found that the difficulty of a communicative act is reflected in the planning times of both players involved in it, indicating that communication involves both recipient design (i.e., communicating by taking into account the interlocutor's stance) and intention recognition. They also found that 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).

2.2.9.2. Insights from failures. Sometimes players engaged in Semiotic Coordination Games fail at developing even a minimal communication system (Galantucci 2005; Scott-Phillips et al. 2009). Such failures provide useful information about the core ingredients for the emergence of communication. As we have seen above, Scott-Phillips et al. (2009) demonstrated that failure is more likely when players are not afforded the possibility of establishing a salient default coordination procedure. Direct comparisons between the behaviors of failing and successful players (Galantucci 2009; Galantucci and Steels 2008) suggested two further conclusions.

The first is that the failures are often due to communicative egocentrism, that is, players' attempts at communicating did not take into account the partners' perspective. Such egocentrism, which has been noted before in spoken conversation (Keysar 2007), seems to be much heightened in the presence of a severe semiotic challenge (Galantucci 2009; Galantucci and Roberts 2012). For example, some players did not use the digitizing pad they had at their disposal to communicate for as long as two consecutive hours, often while the partner tried repeatedly to initiate some form of communication. These players sometimes made use of the signs generated by the partner, demonstrating an understanding of the basic dynamics of the game. However, the idea of reciprocating the communicative acts initiated by the partner was not obvious to them, suggesting a severe egocentric limitation. This conclusion is consistent with the behavior of other players who were successful at the game but developed signs which had different meaning depending on something that they privately controlled—the trajectory of the stylus on the digitizing pad—but which was not publicly perceivable. For example, some players drew a vertical line on the pad from top to bottom to indicate 'going down' and from bottom to top to indicate 'going up'. Given the constraints of the communication medium (Figure 1A), the two drawings led to identical tracings on the screen seen by the partner (as well as by the drawer). However, the drawings *felt* different to the tracer's hand and were thus used as different signs.

The second conclusion is that explicit negotiation does not rescue failing players. In the Semiotic Coordination Game developed by Galantucci and colleagues (Galantucci 2005; Galantucci et al. 2003), players controlled agents which had a simplified human body, with clearly distinguishable front and back sides. When the agents were in the same room of the game environment, players could see both of them and could use the orientation of the agent's front side, as well as the agent's location and movements in the room, for communicative purposes. For example, players could move the agent they controlled close to a door in the room, make it face the door, and move it in an oscillating manner near it. Behaviors of this kind could be readily interpreted by the partner as ''pointing'' at the door and allowed players to establish relations between the meaning of the signals produced with the digitizing pad and the objects pointed to. Surprisingly, however, Galantucci (2009) found that explicit negotiations of this kind were not beneficial for many players, a finding which parallels a finding in research on human dialogue (Garrod and Anderson 1987). This conclusion is consistent with the conclusion of the study by Scott-Phillips et al. (2009) that succeeding in a Semiotic Coordination Game is harder when communication cannot be bootstrapped implicitly.

2.2.10. Implications of this theme for linguistics

The last theme we presented in the review exemplifies another way in which ES can provide useful contributions to linguistics. When experimental semioticians study the very emergence of human communication, they provide new opportunities for cross-breeding linguistics with the rest of cognitive science. In what follows we describe two examples of such opportunities.

2.2.10.1. Reducing the gap between human and animal communication. Contemporary cognitive science has devoted much effort to understanding how animal communication works and how it differs from human communication (e.g., Oller and Griebel 2004). ES could contribute to this enterprise by offering a bare-bones description of human communication. For example, a number of primatologists have been focusing on the question

of whether our closest relatives in the animal kingdom possess Theory-of-Mind capacities (Call and Tomasello 2008). This is a very interesting enterprise in its own right but, if the goal is to ascertain whether or not these creatures have a critical cognitive ability for human language, it may go beyond what is necessary.

As mentioned above, people's failures in the face of challenging ES tasks reveal severe egocentric biases in communication (Galantucci 2009; Galantucci and Roberts 2012). The fact that people do not seem to exhibit such severe biases outside of the laboratory highlights the power of the communicative scaffolding provided to humans by established languages (cf., Vygotsky 1978). However, even when people are speaking their own languages, they still show subtle limits in using Theory of Mind (Keysar 2007). In other words, it is unclear to what extent human language depends on the use of complex Theory-of-Mind operations. Until that is ascertained, measuring the extent to which non-human animals are capable of such operations may not be necessary in assessing their potential for developing sophisticated forms of communication.

2.2.10.2. Reducing the gap between communication and joint action. Experimental semioticians interested in the very emergence of communication use methodologies which are similar to those used by researchers who study joint action in humans (Sebanz et al. 2006), and a cross-breeding between these two lines of research is a concrete possibility (Galantucci and Sebanz 2009). This may lead to new insights because in human interaction the distinction between communicative (e.g., de Ruiter et al. 2007; Scott-Phillips et al. 2009) and non-communicative behaviors (e.g., Richardson et al. 2007; Shockley et al. 2003) is rather subtle and there may be something to learn about communicative behavior by looking at simpler forms of behavioral coordination. Indeed, a current theory about dialogue (Pickering and Garrod 2004) involves coordination at linguistic levels which are often not thought to be communicative (e.g., speech rate) and psychologists have begun to propose that the scientific investigation of language is an integral part of social psychology (Tylen et al. 2010). In other words, de Saussure's vision, with which this paper opened, is finally becoming reality.

3. Conclusions

In the introduction we argued that Experimental Semiotics complements General Linguistics. As we have pointed out a number of times throughout the paper, novel communication systems which emerge in the laboratory exhibit a number of natural language's properties. By studying these systems we can learn something about the basis of human language and how it might have evolved from non-human communication systems. In many respects ES demonstrates that what were often considered specific features of human languages (i.e., compositionality, arbitrariness of signs etc.) turn out to be features of human communication in general. Commonly they emerge with use of alternative novel communication systems and seem to have something to do with human interaction and reciprocity in general (Hasson et al. 2012).

Nevertheless, ES also has its limitations. In particular studies so far have used linguistically experienced human adults. Some might argue that their performance in any novel communication task is going to be contaminated by this experience. However, we are optimistic that this limitation can be addressed with studies involving different populations such as artificial agents, 'pre-linguistic' infants, or non-human primates.

More generally, Experimental Semiotics adds to the methodological armory of students of language and of its evolution.

Short Biographies

Bruno Galantucci is an Assistant Professor in the Department of Psychology at Yeshiva University, where he directs the Experimental Semiotics Laboratory, and a research affiliate at Haskins Laboratories. He has conducted research on the psychology of language, including speech perception, word recognition and sentence processing. In the last few years, he has focused on studying experimentally how humans establish and develop novel forms of communication.

Simon Garrod is Professor of Cognitive Psychology at the Institute of Neuroscience and Psychology, University of Glasgow. He directs the Centre for Social Interactions in Glasgow and has published extensively on various aspects of language and communication. His current interest is on the various roles of interaction in supporting human communication.

Gareth Roberts is a Postdoctoral Research Associate in the Department of Psychology at Yeshiva University and a member of the Experimental Semiotics Laboratory. His PhD dissertation, completed in 2010 at the University of Edinburgh, used experimental methods to investigate the effect of in-group/out-group dynamics and frequency of interaction on linguistic divergence. His main research interest is in using experimental methodologies to understand how and why languages change.

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Notes

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[1] By 'language' we intend a human communication system which supports the expression of an unbounded variety of meanings (e.g., speech, sign language, Tadoma). The more general term 'human communication system' refers to any form of communication used by humans (e.g., speech, body language, road signs).

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