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## Scratching Beneath the Surface: Intentionality in Great Ape Signal production

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42 lead the revision of the paper.  
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# Scratching Beneath the Surface: Intentionality in Great Ape Signal production

Kirsty E. Graham<sup>1</sup>, Claudia Wilke<sup>1</sup>, Nicole J. Lahiff<sup>1</sup>, Katie E. Slocombe<sup>1</sup>

Affiliation: <sup>1</sup>Department of Psychology, University of York, York, YO10 5DD, UK

## Abstract:

Despite important similarities having been found between human and animal communication systems, surprisingly little research effort has focussed on whether the cognitive mechanisms underpinning these behaviours are also similar. In particular, it is highly debated whether signal production is the result of reflexive processes, or can be characterised as intentional. Here, we critically evaluate the criteria that are used to identify signals produced with different degrees of intentionality, and discuss recent attempts to apply these criteria to the vocal, gestural, and multimodal communicative signals of great apes and more distantly related species. Finally, we outline the necessary research tools, such as physiologically validated measures of arousal, and empirical evidence that we believe would propel this debate forward and help unravel the evolutionary origins of human intentional communication.

**Keywords:** Intentional communication, signal production, vocalisations, gestures, language evolution

## 25 Introduction

26  
27 The evolution of language remains one of the biggest unsolved puzzles in  
28 human origins. The complexity of human language far exceeds the complexity seen  
29 in the communication systems of any other extant primate species. However, we  
30 don't know nearly enough about the cognitive underpinnings of non-human  
31 communication to determine what changed in our early hominin ancestors. Because  
32 behaviour does not fossilise, it is imperative to look to the behaviour of other species  
33 and take a comparative approach in the study of language evolution. In recent  
34 decades, a growing focus on communication in non-human great apes, monkeys,  
35 and more distantly related species has started to reveal a variety of shared abilities.

36 The study of animal behaviour has a long history of considering non-human  
37 species as "automatons", machines that take input from their surroundings and  
38 automatically produce an output. Sensory input enters the black box, and behaviour  
39 comes out. For many research purposes that is an entirely adequate approach, but  
40 in comparative psychology the question should be "what is happening inside the  
41 black box?" (1). In order to understand the evolution of language, researchers must  
42 ask questions about the cognitive abilities involved in other species' communication.  
43 This is a real challenge, and hence many animal communication studies focus on  
44 describing the signals and signal sequences that are produced on a purely  
45 behavioural level. One danger of this approach is that behaviour in non-humans and  
46 humans can appear similar, but if the surface similarity in behaviour is underpinned  
47 by very different cognitive processes, then they may not tell us much about how  
48 human language evolved (2). We need to start to scratch beneath the surface and  
49 ask questions about the cognition that underpins signal production. One of the first  
50 questions that arises when we start to look deeper is whether signals are produced  
51 intentionally in non-humans.

52 Human language is intentional – we do not produce sentences as automatic  
53 responses to stimuli, rather we intend to alter the behaviour or mental state of other  
54 individuals (3,4). Intentionality is a difficult concept to define and operationalise, and  
55 researchers studying gestural, vocal, and facial signals have tackled this challenge in  
56 different ways. So we start this review paper by offering some definitions of  
57 intentional signal production and outlining the criteria that are most commonly used  
58 to identify intentional communication in other species. We then give an overview of

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3 59 evidence for intentional communication in non-human primates and other more  
4 60 distantly related species. Next, we critique current approaches to assessing  
5 61 intentional communication discussing (i) the inconsistency in the application of  
6 62 intentionality criteria; and (ii) the validity of the criteria themselves. Finally we  
7 63 suggest future directions for research, including the need for physiologically  
8 64 validated behavioural measures for arousal, and the potential benefits of refocussing  
9 65 attention back on experimental assessments of second-order intentionality.  
10 66 Traditionally, researchers across different species and different communication  
11 67 systems have tended to tackle similar problems from different angles. We aim to  
12 68 bring together approaches from research on vocalisations, gestures, and facial  
13 69 expressions, across a number of species, and propose ways forward for the study of  
14 70 intentionality in non-human communication.  
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## 26 72 **Defining intentional communication**

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29 74 To begin with, we have the problem of defining intentional communication in a  
30 75 way that can be operationalised and tested in non-verbal species. Varying definitions  
31 76 of intentional signal production have hindered the progression of our knowledge in  
32 77 this domain. The term 'intentionality' originated in philosophy, introduced by Franz  
33 78 Brentano, referring to puzzles of representation, linking together the philosophies of  
34 79 mind and language (5). Brentano believed that intentionality was a prevalent  
35 80 property in all mental states, from beliefs and hopes to love and hatred, with these  
36 81 always being about or referring to a specific target, property, or matter of fact (real or  
37 82 imagined). Notably Brentano's thesis suggested that intentionality is *only* a mental  
38 83 phenomenon, and cannot exist in non-mental constructs such as sentences of  
39 84 natural languages. However, Searle (6) and Grice (4,7) reinterpreted intentionality as  
40 85 it might apply to actions and communication, moving it beyond Brentano's original  
41 86 formulation. Grice's early conceptualisations of intentional signalling require  
42 87 sophisticated meta-representation from both the recipient and the signaller (4,7,8).  
43 88 He proposed that when producing an intentional signal, it is explicitly clear that the  
44 89 signaller is communicating *something* to the recipient (also known as ostension), and  
45 90 the fact that the signal is communicative is mutually understood by both participants  
46 91 (7,8). That this is ubiquitous in (adult) human communication is uncontroversial, but it  
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3 92 is debated to what extent non-linguistic communication systems can be deemed  
4 93 intentional based upon Gricean views (2,9).

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6 94 Questions have recently been raised about the appropriateness of using  
7 95 Gricean intentionality and meaning as a way of assessing non-human  
8 96 communication, given that Grice's definitions were rooted in linguistics rather than  
9 97 including any form of expressive communication (10,11). However the Gricean  
10 98 approach remains the dominant approach in animal communication, with most  
11 99 researchers using Dennett's intentionality framework (4) which offers more graded  
12 100 steps towards the complex meta-representation required for full-blown Gricean  
13 101 intentional communication. According to this framework, zero-order intentionality  
14 102 requires no mentality involved in signalling, whilst first-order requires that the  
15 103 signaller intends to signal in order to change the *behaviour* of the recipient, and  
16 104 second-order requires that intentions to signal are combined with mental state  
17 105 attributions (12). Using food calls as an example, zero-order intentional  
18 106 communication would be that the signaller calls on arrival at a food patch as a result  
19 107 of increased arousal or excitement triggered by food discovery. For first-order  
20 108 intentional communication, the signaller would call to affect their audience's  
21 109 behaviour, i.e. to recruit group members to join the signaller at the food patch.  
22 110 Finally, for second-order intentional communication, the signaller would call to inform  
23 111 ignorant audience members about the food patch, thus altering their mental state  
24 112 from ignorant to knowledgeable.

25 113 Because Dennett's framework offers tractable definitions for differing levels of  
26 114 intentionality, that can be operationalised, it has found popularity among animal  
27 115 communication researchers (12–14). Focussing on first-order intentionality (altering  
28 116 of behaviour) loosens previously strict criteria for mental state understanding, and  
29 117 offers a valuable stepping stone from no intention to higher levels of intention.  
30 118 However, many researchers still believe that second-order intentionality (requiring  
31 119 attribution of mental states) is the most relevant cognitive precursor to the evolution  
32 120 of language. Both lab and field experiments have been designed to try and identify  
33 121 second-order vocal production in primates, where researchers have tested whether  
34 122 the knowledge state of the audience mediates call production in the signaller (15,16).  
35 123 However, before second-order intentional signal production is tackled, the first logical  
36 124 step seems to be to distinguish first-order from zero-order intentional signal  
37 125 production. This approach has been recently advocated (9,12), particularly as

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3 126 children can struggle with high-order meta-representations (17), yet do not struggle  
4 127 with language, and communication in adults does not always rely on such high-order  
5 128 representations (18). In order to identify first-order intentional signal production a  
6 129 clear framework with observable behavioural criteria is required.

10 130 Townsend et al. provide such a framework (12), bringing together markers  
11 131 that have previously been used to identify first-order intentional communication in  
12 132 prelinguistic humans and non-human animals. They propose that an animal has  
13 133 communicated with first order-intentionality if the following three conditions are met:  
14 134 i) a signaller acts with a goal when communicating to a recipient; ii) the signaller  
15 135 exhibits volitional control over recipient-directed signal production to obtain their  
16 136 communicative goal; and iii) that the recipient alters their behaviour in a way that is in  
17 137 line with the signaller's goal. The value of this framework lies in its ability to define  
18 138 the intentionality of a signal using directly observable behaviour. The main limitation  
19 139 of the framework is that, as highlighted in the original paper and discussed in more  
20 140 depth later in this article, all the behavioural markers designed to diagnose first-order  
21 141 intentional signal production could also be explained by zero-order intentional  
22 142 processes. Thus the validity of the criteria used is unclear. In order to meaningfully  
23 143 discuss the validity and use of the criteria, we will first outline the criteria and the  
24 144 empirical evidence currently used to claim first-order intentionality in different  
25 145 communicative modalities.

27 146 To test Townsend et al.'s first criterion that signals are produced to meet a  
28 147 goal, the signaller should continue to signal until a 'stopping rule' has been satisfied  
29 148 and the goal met. That is, when a recipient does not respond to a signal immediately,  
30 149 the signaller should persist or elaborate in signalling in pursuit of their goal. In such a  
31 150 case, the recipient response that terminates these communicative attempts can be  
32 151 identified as the putative goal of the initial signal (19–21).

33 152 A broader range of behaviours centred on social use of a signal are  
34 153 suggested to help identify the production of volitional and recipient-directed signals  
35 154 (criterion (ii)). The most rudimentary marker concerning social-usage is the presence  
36 155 or absence of potential recipients. While humans sometimes produce signals in  
37 156 private, for non-humans, signals that are produced in the absence of an audience  
38 157 are presumed to be a product of underlying arousal-based mechanisms. For  
39 158 instance, if a monkey sees a snake and produces an alarm call when no other

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3 159 monkeys are around, it is assumed that the signal was produced as a result of  
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5 160 elevated arousal or fear triggered by predator discovery.

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7 161 Building from the simple presence of a potential recipient, researchers also  
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9 162 search for complex audience effects, where the composition of the audience can  
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11 163 mediate both the rate and structure of signals. For instance, vervet monkeys alarm  
12  
13 164 call more frequently in the presence of kin than non-kin (22), and chimpanzees alter  
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15 165 the structure of their victim screams given to severe aggression if high ranking  
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17 166 bystanders are in the audience (23). These more complex audience effects show  
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19 167 selective control over signal production, indicating that they are voluntarily produced  
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21 168 and directed at specific recipients.

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23 169 Decisions regarding when and what type of signal to produce can also be  
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25 170 affected by the attentional state of the recipient(s). Visual signals produced to  
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27 171 inattentive recipients are likely to be ineffective, because the recipient cannot see the  
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29 172 signal. If the signaller intends to communicate to the recipient, they should produce a  
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31 173 signal that is perceptible to the recipient – avoiding silent-visual signals when the  
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33 174 recipient is inattentive and relying on audible or tactile signals in these  
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35 175 circumstances. This selectivity indicates not only that the signaller may be engaging  
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37 176 in basic perspective taking, but also that they understand the most effective means  
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39 177 by which to achieve their goal. Before selecting the appropriate signal, the signaller  
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41 178 should check where the recipient is looking, and then continue to visually monitor the  
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43 179 recipient for a response. Together these behaviours are commonly known as  
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45 180 “audience checking”, which is a frequently used marker of first-order intentional  
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47 181 communication, as it seems to indicate that the signaller is directing the signals at a  
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49 182 recipient and then expecting a response.

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51 183 The final criterion shifts focus from signal production, instead requiring a  
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53 184 consistent behavioural response from the recipient that is appropriate for the signal  
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55 185 given (e.g. moving away from the perceived threat that elicited the signaller’s alarm  
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57 186 calls). The recipient response needs to be consistent across multiple signalling  
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59 187 events, and needs to occur immediately after a signal more frequently than at other  
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188 times (chance level of response behaviour occurring), in order to show that the  
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190 response is connected to the signal. This criterion is important to demonstrate that  
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signals are effective, and that recipients seem to understand the signal or the  
signaller’s goal in some manner.

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3 192 To date, studies have focused on identifying behavioural indicators of  
4 193 intentionality (e.g. persistence, gaze alternation or social usage) without reaching a  
5 194 consensus on how these should be applied in methodology. Surprisingly, there is no  
6 195 established acceptable number of behavioural indicators required to classify a signal  
7 196 as intentional (24). The definition offered by Townsend et al. likewise does not  
8 197 specify this (12), but instead requires that a signal demonstrates at least one  
9 198 behaviour from each of the three broader criteria in order to be deemed intentional.  
10 199 Defining intentionality in these terms has the benefit of being conservative enough to  
11 200 avoid claims for intentionality with only one behavioural indicator, and at the same  
12 201 time is still empirically viable and inclusive across taxa.  
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### 23 **Primate Evidence**

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25 205 Traditionally, primate vocalisations, gestures, and facial expressions have  
26 206 been studied in isolation with researchers specialising in just one of these types of  
27 207 communication (17, but see 18), and perhaps as a result have followed different  
28 208 approaches to looking at intentionality. Gesture researchers have been the most  
29 209 explicit in their treatment of intentional communication. Intentional gestures were first  
30 210 observed in captive chimpanzees (27,28), and have now been observed in all four  
31 211 species of non-human great apes (Table 1). Following this early work on  
32 212 chimpanzees, intentional production has been routinely used as a prerequisite for a  
33 213 body movement to be identified as a gesture. As it is difficult to define the onset and  
34 214 offset of gestures based on physical properties, researchers used intentional  
35 215 production as a way to differentiate communicative movements from non-  
36 216 communicative movements that are produced for other purposes. This is in stark  
37 217 contrast to vocal and facial signals which are defined in terms of their physical  
38 218 properties, with the degree of intentionality underpinning a signal a matter for  
39 219 separate investigation. Claims of intentionality in gestures are therefore rather  
40 220 circular, as gesture researchers are a-priori selectively focussing on body  
41 221 movements that appear intentional and therefore it is not surprising that these  
42 222 signals go on to meet behavioural markers for intentionality.

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57 223 To be classified as a gesture, some of the following behavioural criteria must  
58 224 be met: it should be directed towards a specific recipient, the signaller should check  
59 225 the attention of the recipient and adjust their signal to match that attention, signallers

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3 226 should wait for a response, and if they do not receive a response they should  
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5 227 continue to produce more signals (29–32). These criteria originate from early  
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7 228 attempts to identify intentional gesture production in preverbal human infants (33),  
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9 229 and attempt to distinguish first-order from zero-order intentional signal production.  
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11 230 Different researchers require different numbers of criteria to be met before assigning  
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13 231 intentionality to the signal or class of signals in question (Table 1), but it is widely  
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15 232 claimed that great ape gestures are produced with first-order intentionality.

15 233 In contrast, vocalisations have traditionally been viewed as automatic, zero-  
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17 234 order intentional signals elicited by specific environmental events (e.g. presence of a  
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19 235 predator (34)). It is only in recent years that markers of first-order intentionality have  
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21 236 been applied to vocal behaviour to challenge this stance (Table 1). On the other  
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23 237 hand, experiments testing second-order intentional signal production have only been  
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25 238 conducted in the vocal domain, not in the gestural domain. Capitalising on the fact  
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27 239 that in many species alarm calls function to refer to predators, experiments have  
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29 240 been designed to test whether alarm calls are produced selectively to ignorant group  
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31 241 members, to change their mental state from ignorant to knowledgeable. Whilst  
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33 242 captive macaques do not mediate their alarm or food calls as a function of their  
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35 243 offspring's knowledge about a predator or food source (15), more promising results  
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37 244 suggest that wild chimpanzees may be more likely to alarm call to individuals who  
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39 245 know less about an ambush predator model (16). There is mounting evidence that  
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41 246 both gestures and (some) vocalisations meet behavioural criteria for first-order  
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43 247 intentionality, and that some may even show evidence of second order intentionality  
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45 248 (35).

43 249 Of the three types of communication, facial expressions have received the  
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45 250 least attention from researchers in terms of their intentional production. The  
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47 251 traditional view of facial expressions is that they are zero-order intentional signals  
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49 252 that are the product of emotional processes. However, although humans produce  
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51 253 facial expressions automatically, we can also produce them intentionally, and so it is  
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53 254 important to ask whether other primates share this ability. Hopkins et al. argue that  
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55 255 chimpanzees have some volitional control over their facial expressions (36), and  
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57 256 more recent studies have demonstrated that great apes modify their facial  
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59 257 expressions if their audience is visually attending to them (37,38). More research is,  
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258 however, needed to determine whether facial expressions meet other intentionality  
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260 criteria.

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3 2604  
5 261 -Table 1-6  
7 2628 263 **Intentional signal production in other species**9  
10 26411  
12 265 Although most research has focussed on intentional signal production in non-  
13 266 human primates, other species have also been the subject of investigation.14 267 Identifying intentional communication in species more distantly related to humans is  
15 268 important, as it may help us to understand the selection pressures that give rise to  
16 269 intentional control over communicative signals, as well as helping us to evaluate the  
17 270 validity and utility of the behavioural criteria being used to identify first-order  
18 271 intentional signal production.19 272 Social usage of signals, the first of the behavioural markers that is said to  
20 273 indicate voluntary control and recipient-directed signal production, is widespread in  
21 274 the animal kingdom. For instance, seminal work on audience effects demonstrated  
22 275 that female ground squirrels produce more alarm calls in the presence of direct kin  
23 276 as opposed to non-kin (39). Similarly, male domestic chickens were found to  
24 277 increase the frequency of food calls when a female was present compared to when  
25 278 they were alone (40), and male Siamese fighting fish produce fewer aggressive  
26 279 signals towards other males, when there is a female audience (41). In fruit flies, the  
27 280 genotypic composition of the social group significantly impacts the overall levels of  
28 281 pheromone signal production, as well as when chemical signals are produced  
29 282 (42,43). Such findings show that complex audience effects are found across taxa,  
30 283 with signals being affected not just by the presence of an audience, but by that  
31 284 audience's composition. We therefore need to question whether volitional control  
32 285 over signal production is in fact widespread in the animal kingdom, or whether  
33 286 audience effects are not strong markers of volitional control.34 287 Miklosi and colleagues (34), move away from basic audience effects and  
35 288 argue that dogs produce intentional 'showing' signals to human owners to indicate  
36 289 the location of a hidden toy. 'Showing' was defined as a communicative action  
37 290 involving both a directional 'pointing' component (head orientation towards the  
38 291 hidden toy) and an attention-getting component (barking and gazing at owner).  
39 292 When the dogs observed an experimenter hiding a toy in one of three inaccessible  
40 293 locations in the room, and the naïve owner then entered, the dogs exhibited gaze

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3 294 alternation between the owner and hidden toy and attention getting behaviours,  
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5 295 significantly more than when they were simply in the room with the owner in the  
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7 296 absence of a hidden toy. While the authors claim that this demonstrates intentional  
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9 297 referential communication, more evidence is required to confirm the intentional  
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11 298 nature of these signals, certainly according to the Townsend et al. framework (12).

12 299 Similar claims of intentional showing behaviour have been made for ravens.  
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14 300 Pika and Bugnyar argue that ravens 'show' objects to conspecific partners (44).  
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16 301 Showing is defined as "picking up a non-food item, holding it up in the beak, head  
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18 302 straight or tilted upwards, and staying in this position" (pg. 2; 44). They report that  
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20 303 such showing 'gestures' were always recipient-directed, and produced at a  
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22 304 significantly higher frequency to attending than non-attending partners, showing  
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24 305 sensitivity to the partner's attentional state. The authors claim that these signals  
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26 306 were goal-directed, based on the signaller looking at the recipient and showing  
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28 307 response waiting. However, without subsequent persistence or elaboration in the  
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30 308 face of an unresponsive partner, there would be insufficient evidence to show that  
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32 309 these gestures were produced in a goal-directed manner according to Townsend et  
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34 310 al.'s criteria (12). These gestures seemed effective in eliciting a positive response  
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36 311 from recipients, in terms of partners orienting towards the signalling bird or object  
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38 312 and subsequently engaging in affiliative, rather than agonistic behaviour, but chance  
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40 313 levels of these responses within these dyads occurring are unclear. In summary,  
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42 314 although this showing behaviour seems under voluntary control and is recipient-  
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44 315 directed, more evidence is needed before the other criteria of goal-directed  
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46 316 production and consistent recipient responses can be confirmed. On the surface,  
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48 317 there seem to be commonalities between this 'showing' behaviour in ravens and  
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50 318 courtship displays involving objects in a variety of avian species, so future research  
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52 319 could usefully apply the intentionality criteria to such displays in non-corvids to see  
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54 320 whether other avian species demonstrate first-order intentional signal production.

55 321 In terms of satisfying all three of the intentionality criteria for signal production  
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57 322 proposed by Townsend et al. (12), perhaps surprisingly, some of the strongest  
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59 323 candidates are two species of fish. Grouper fish and coral trout perform a  
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324 'headstand' to signal the location of prey to cooperative hunting partners, and this is  
325 considered to be referential communication (45). This signal meets the main criteria  
326 for intentional signalling, including being seemingly goal-directed (showing  
327 persistence, elaboration, and cessation when goal is met), recipient-directed, and

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3 328 eliciting a response from the recipient that is in line with the goal. It is one of the few  
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5 329 empirical demonstrations that meets all of the intentionality criteria set by Townsend  
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7 330 et al. in a single communication system (12), providing more solid evidence than  
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9 331 most primate species to date. More recently, convincing evidence of intentional  
10  
11 332 communication has also been found in Arabian babblers (46), and it is likely that the  
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13 333 wider application of Townsend et al.'s criteria will reveal more intentional  
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15 334 communication across a broader range of species.

15 335         These studies suggest that a diverse range of species deploy some form of  
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17 336 intentional signalling and that intentional signal production may not be restricted to  
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19 337 large-brained mammals. It is therefore unclear whether first-order intentional signal  
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21 338 production is simply widespread in the animal kingdom, or whether different  
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23 339 processes are underpinning the same behavioural patterns in different taxa. Given  
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25 340 that the behavioural markers are designed to probe specific underlying cognitive  
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27 341 processes, the validity of these measures is questioned if we attempt to explain  
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29 342 away the findings of first-order intentional signalling in distantly related, relatively  
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31 343 small-brained animals by claiming that they might be the product of different  
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33 344 underlying processes. The findings of first-order intentional signal production in  
34  
35 345 distantly related species provide insights into the types of problems and pressures  
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37 346 that drove intentional communication to evolve, but they also call into question the  
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39 347 importance of first-order signal production as a stepping stone in the evolution of  
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41 348 human language.

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### 41 350 **Current Limitations**

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43 352         Our understanding of intentional communication in non-humans is currently  
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45 353 limited by two main issues: (i) the diversity of evidence used to claim intentional  
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47 354 signal production and consequent lack of comparability between studies, and more  
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49 355 importantly, (ii) the validity of the behavioural criteria used to distinguish first-order  
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51 356 from zero-order intentional communication. For those who consider the current  
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53 357 criteria to be valid, or the best tools currently available, the lack of rigorous  
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55 358 application of these criteria across studies remains problematic, and this issue will be  
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57 359 addressed first.

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59 361 *Lack of consistency in application of intentionality criteria*

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5 363 The claim of intentional signal production can be based on highly variable  
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7 364 types and amounts of data. As Table 1 shows, the number of criteria examined is  
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9 365 very inconsistent across studies; some studies only require 1/3 or 1/4 criteria to be  
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11 366 met to count as an intentional signal, while other studies require that 1/1 or 3/3  
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13 367 criteria are met. Some variation should be expected, as not all criteria are relevant to  
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15 368 each species (e.g. a standard 1-2s “response waiting” period that was designed  
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17 369 around chimpanzee data may be too short or too long for other primate species) or  
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19 370 modality (several criteria are specific to visual signals). However, it also seems that  
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21 371 there is additional variability in the stringency with which the behavioural criteria are  
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23 372 used by different researchers before accepting a signal as intentionally produced,  
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25 373 and such variability is problematic.

26 374 A better approach may be to use all criteria and list how many signals were  
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28 375 eliminated at each stage: for example, the study started with 400 gesture instances,  
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30 376 but 12 had no audience checking, 23 had no response waiting, and 15 had no  
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32 377 persistence, which left 350 gestures that met all criteria for intentionality. One  
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34 378 problem with this approach is that goal-directedness can often only be tested when  
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36 379 the recipient does not immediately respond and provides the opportunity for the  
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38 380 signaller to persist or elaborate to achieve their goal; so what to do with signals that  
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40 381 elicit an immediate appropriate response is unclear, as we can't use the established  
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42 382 markers for goal-directedness in these cases.

43 383 There is also an important difference between studies that collect systematic  
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45 384 data to test whether a certain signal or class of signals meet specific criteria for first-  
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47 385 order intentionality (e.g. (38,47,48)) and studies, most of them gestural, where  
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49 386 intentional production criteria are used as pre-conditions to screen potential  
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51 387 gestures, so that only body movements that are produced intentionally are  
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53 388 considered in later analysis (e.g (20,21,49)). When systematic data is presented,  
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55 389 there is variation in whether baseline data on the behaviours of interest are  
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57 390 associated with communicative signals at a level significantly above chance. For  
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59 391 instance looking at group members is a common behaviour that, when produced in  
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392 temporal association with a signal, we interpret as ‘audience checking’, and this is  
393 sometimes used as the sole criterion for identifying first-order intentional signalling  
394 (Table 1). However, we first need to know the chance level of these two behaviours  
395 co-occurring to be able to say that looking at group members really is related to

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3 396 signal production. One approach is to statistically compare the likelihood of the  
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5 397 intentional behaviour marker occurring with signal production events and non-signal  
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7 398 production events (e.g. (50)). In cases where inferential statistics are applied to the  
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9 399 data, one can infer that on average, intentionality markers are likely to co-occur with  
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11 400 signals at above chance rates, but it is much harder to interpret purely descriptive  
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13 401 data. For instance, Gruber and Zuberbühler report 9 events where a chimpanzee  
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15 402 vocal signal was repeated in the face of an unresponsive audience 0-13 minutes  
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17 403 after the original call (40). Unfortunately, without comparison to signaller behaviour in  
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19 404 all events with unresponsive and responsive audiences, it is hard to conclude from  
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21 405 these data that chimpanzees generally persist with this call type until they meet their  
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23 406 goal.

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25 407 When the behavioural criteria for intentional signal production are used as  
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27 408 preconditions to identify 'true' gestures, there is also variability with the number of  
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29 409 criteria that a gesture instance has to meet. Many researchers only require a signal  
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31 410 to meet one of a set of criteria that often includes 'response waiting', which typically  
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33 411 means that after a signal, no subsequent signals are produced by the signaller for at  
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35 412 least 2 seconds (13 out of 27 papers in Table 1 use "response waiting" as a criterion,  
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37 413 and 10 out of those 13 studies required no other criteria to be met). Response  
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39 414 waiting can be relevant to identifying intentionality when combined with persistence if  
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41 415 the recipient is unresponsive, but response waiting in isolation (producing a single  
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43 416 signal rather than a sequence of signals) has many explanations, most unrelated to  
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45 417 intentionality. Thus response waiting on its own is not adequate to demonstrate  
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47 418 intentional communication, but often that is exactly what researchers are using.

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49 419 There is also variability in whether each individual signalling event is  
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51 420 assessed against intentionality criteria (20,21,49), or whether one instance of  
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53 421 intentional use of a specific signal by a specific individual is then extrapolated to all  
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55 422 signals of the same type produced by that same individual (30). To summarise, there  
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57 423 is a large amount of variability in the rigour with which researchers ensure their  
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59 424 signals meet the behavioural criteria for intentionality, and whilst some variation is  
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61 425 inevitable, we argue that the current degree of variation makes comparisons across  
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63 426 studies, species, and modalities extremely difficult.

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65 427 Trying to understand the cognitive processes in the signal producer, with a  
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67 428 view to informing theories of language evolution, is a difficult endeavour and in terms  
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69 429 of examining different signal types produced in different modalities, in different

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3 430 contexts, and across species, we have barely scratched the surface. Thus  
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5 431 comparability across studies is really important, as an individual research team can  
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7 432 only make small contributions to this substantial challenge. Even when comparisons  
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9 433 are possible, interpretation of results from different studies can also be challenging.

10 434 A prominent example of conflicting interpretations about the same signal  
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12 435 comes from claims of zero- to second-order intentional production made for the  
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14 436 same type of chimpanzee alarm call. These alarm calls, called either 'soft huus' (47)  
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16 437 or 'alert hoos' (16,51), were elicited by snake models presented by two different  
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18 438 research groups. Schel et al. (47), presented wild chimpanzees with a moving  
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20 439 python model, and found that the calls were given in the absence of an audience,  
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22 440 whilst visually fixating on the snake (little audience checking), and with a calling rate  
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24 441 unaffected by the arrival of new potentially ignorant individuals. When considered in  
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26 442 bouts with other types of alarm calls (alarm huus and waa barks), positive evidence  
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28 443 for persistence towards a goal and gaze alternation was found, but the contribution  
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30 444 of soft huus within these mixed call type bouts is unclear. Thus Schel et al.  
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32 445 concluded that soft huus, at least in immediate response to the snake, were best  
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34 446 characterised as zero-order intentional individualistic expressions of fear (47). In  
35  
36 447 contrast, experiments with the same community of wild chimpanzees using a static  
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38 448 model of a snake, showed that the relative knowledge state of the receivers  
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40 449 mediated the production of alert hoos and the researchers concluded that these calls  
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42 450 were produced with second-order intentionality (16).

43 451 It is not at all clear what to make of this pattern of results: the same call type  
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45 452 tested with a snake presentation experiment to the same community of chimpanzees  
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47 453 within the space of a few years, yet despite these commonalities, the data point to  
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49 454 very different conclusions. One way to reconcile these differences is to accept that  
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51 455 there is variability in the degree of intentional control involved in the production of a  
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53 456 signal, depending on the precise context (e.g. species and movement of predator  
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55 457 model). Anecdotally, humans also experience varying degrees of voluntary control  
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57 458 over their signal production. For instance, a normal ability to inhibit swearing in front  
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59 459 of senior colleagues can be lost in a situation of extreme fear, such as almost  
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61 460 crashing a car. If we accept this, however, it indicates that the intentionality of signal  
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63 461 production must be assessed on an event by event basis, and extrapolation of  
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65 462 intentional production of one instance of signal production to another, as is  
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67 463 sometimes done in gesture research (e.g. (30)), is likely inadvisable. These

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3 464 conflicting findings demonstrate the value of replication and multiple groups working  
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5 465 on the same questions, but wider discussion of how to make sense of seemingly  
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7 466 contradictory findings such as these is needed.

8 467 In conclusion the variability across many dimensions in how the current  
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10 468 behavioural criteria for first order intentionality are applied, means that valid  
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12 469 comparisons across studies and modalities is essentially impossible. If we are to  
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14 470 continue to use these criteria, a more rigorous and uniform approach is required.

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17 472 *Validity of the behavioural markers for first-order intentional signal production*

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20 474 Perhaps the most serious issue that requires attention is the validity of the  
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22 475 behavioural criteria used to identify instances of first-order intentional communication  
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24 476 and distinguish them from zero-order intentional communication. Whilst the  
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26 477 behavioural criteria all make intuitive sense, they are all also open to lower level,  
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28 478 zero-order intentional explanations (12,24), which means they may not be measuring  
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30 479 first-order intentionality at all. First, let's consider goal-directedness as measured by  
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32 480 persistence or elaboration in signalling when faced with an unresponsive recipient or  
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34 481 an inappropriate audience response. It is sometimes easiest to imagine how a  
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36 482 behaviour may be driven by a lower-level mechanism if you imagine an example with  
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38 483 a signal that is assumed to be driven by zero-order intentional processes. Rightly or  
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40 484 wrongly, we have traditionally assumed that primate facial expressions are read-outs  
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42 485 of emotional arousal. In a case where a subordinate chimpanzee is fearful of  
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44 486 approaching a dominant, they may produce a silent bared teeth face and both this  
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46 487 signal and the fearful emotion presumed to underpin it, persist until the dominant  
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48 488 individual reassures the subordinate, at which point the fearful emotion decreases  
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50 489 and the silent bared teeth face disappears. In this scenario, the production of the  
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52 490 silent bared teeth face would meet the criterion for persistence until the goal of  
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54 491 eliciting reassurance from the dominant was met, but it may have been driven by  
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56 492 purely zero-order intentional processes. A high level of emotional arousal may not  
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58 493 only trigger the production of a single signal, but a number of signals that share  
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60 494 similar functions. If a number of closely related signals share a common arousal  
495 based production mechanism, then this could also account for elaboration, where  
496 more than one signal type is used until the goal is achieved. To return to the above  
497 example, the arousal state associated with fear of approaching a dominant may

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3 498 trigger submissive crouching behaviour, or pant grunt vocalisations, in addition to the  
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5 499 silent bared teeth facial expression, and this constellation of behaviours would meet  
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7 500 the criteria of elaboration of signals to meet a goal.

8 501         There is equal uncertainty as to the mechanisms underpinning the  
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10 502 behavioural criteria for a signal being produced voluntarily and in a recipient-directed  
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12 503 manner. Producing a communicative signal selectively in the presence of an  
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14 504 audience (social use), may be driven by arousal. Research with a range of species  
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16 505 indicates that arousal levels are higher when in a social group compared to alone  
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18 506 (52) and thus it is plausible that in an arousal-based system, the threshold for signal  
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20 507 production is usually only met when an audience is present and base levels of  
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22 508 arousal are elevated. More complex audience effects, such as only producing  
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24 509 signals in the presence of kin, friends, or higher ranking individuals may be more  
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26 510 compelling, but it is also possible that the presence of certain individuals differentially  
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28 511 affects arousal. The evidence for arousal increasing differentially with the presence  
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30 512 of different individuals is less apparent, but this possibility needs testing and ruling  
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32 513 out before we can say with certainty that complex audience effects do not arise from  
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34 514 an arousal based signal production system. Equally, cases where signals are  
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36 515 contingent on the behaviour of the audience (e.g. individual alarm calls until all other  
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38 516 group members have alarm called) could also arise from changes in arousal. In  
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40 517 humans we know that heartrate in a speaker can be increased by negative  
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42 518 behavioural responses in the audience (e.g. (53)) and behaviour in audience  
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44 519 members may affect autonomic arousal levels in signal producers across species.

41 520         Sensitivity to the recipient's attentional state, in terms of only producing visual  
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43 521 signals when a partner is attending, appears to be a strong marker of intentional  
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45 522 signal production, as it may involve perspective taking, however this behaviour could  
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47 523 also be a result of learned discriminations. Individuals may learn over their lifetime  
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49 524 that the face of a recipient is one of the necessary eliciting stimuli for effective  
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51 525 production of visual signals, possibly in a similar way to infant vervet monkeys  
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53 526 learning to narrow the type of stimuli that elicit their eagle alarm call (24). If this  
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55 527 scenario is correct, then looking for the stimulus of a conspecific face before  
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57 528 signalling (like visual examination of an aerial object in vervet monkeys before alarm  
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59 529 calling) would also result in what has been described as 'audience checking'  
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60 530 behaviour.

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3 531 Although audience checking where the signal producer looks at the signal  
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5 532 recipient before or during signal production, may have a low-level conditioning  
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7 533 explanation for visual signals, there doesn't seem to be an obvious lower-level  
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9 534 explanation for why primates should look to audience members before emitting a  
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11 535 vocal signal, as visual attention in the recipients is not necessary for vocal signals to  
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13 536 be effective.

14 537 In summary, as has been previously highlighted, each of the criteria has an  
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16 538 alternative zero-order intentional explanation, however the empirical evidence  
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18 539 supporting these alternative explanations is highly variable and many remain simple  
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20 540 theoretical possibilities. It has been previously argued that providing convergent  
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22 541 evidence from diverse markers, provides more robust evidence and more likely  
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24 542 attributable to a single mental ability (intentionality) than a series of arousal and  
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26 543 conditioning based explanations (12,24), and whilst we agree that convergent  
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28 544 evidence across markers is stronger than evidence from a single marker, more  
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30 545 discussion of the validity of these criteria is needed.

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### 31 547 **The way forward**

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34 549 While there are extensive claims of first-order intentional communication in  
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36 550 other animal species, our current ability to rigorously assess such intentionality is  
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38 551 sadly limited, and we need to look for new alternatives. We provide two main  
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40 552 suggestions for moving forward: (1) directly assessing arousal during  
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42 553 communication, which would allow us to determine the degree to which high levels of  
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44 554 arousal elicit certain signals; and (2) focussing experimentally on second-order  
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46 555 intentionality, as evidence for second-order intentionality implies the existence of  
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48 556 first-order.

48 557 It is worth noting that although there are plausible emotional arousal based  
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50 558 explanations for the behavioural criteria for first-order intentional signal production,  
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52 559 few of them are underpinned by hard evidence. Unlike our understanding of  
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54 560 conditioning, which is built on decades of experimental data and theoretical models,  
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56 561 our understanding of how and when arousal affects behaviour is relatively poor.  
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58 562 Despite this, arousal is often offered as a post-hoc explanation for a startlingly wide  
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60 563 array of behaviours and phenomena, and because the tools we have for assessing  
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565 564 arousal are currently inadequate, it is very difficult to rule out arousal accounting for

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3 565 interesting behaviours. Yet, because arousal is the lower level of explanation for  
4 566 behaviour, the onus is on the researcher wanting to claim a higher level mechanism  
5 567 to rule out the lower level explanation. In most cases this is impossible, because the  
6 568 current tools for evaluating emotional arousal in primates are inadequate: they are  
7 569 either prohibitively expensive and work on a timescale incompatible with  
8 570 understanding individual signal production events (e.g. hormone analysis), require  
9 571 minimal movement in the animal (thermal imaging), or need expensive specialist  
10 572 equipment (pupilometry via eyetracking equipment).

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17 573 Current techniques for measuring dynamic changes in arousal levels are  
18 574 therefore incompatible with freely-moving, naturally-behaving primates interacting  
19 575 with one another and, unfortunately, that is the only kind of primate who will produce  
20 576 the meaningful social signals that we are seeking to understand. This means that  
21 577 most researchers interested in signal production (including ourselves) have not been  
22 578 able to address the contribution of arousal to signal production, and have essentially  
23 579 ignored it. This has led us to the situation in which we currently find ourselves, where  
24 580 considerable research effort is being invested in trying to establish whether signals  
25 581 are produced with first-order intentionality, with no certainty that any of our measures  
26 582 are valid.

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34 583 Research to produce physiologically validated behavioural measures of  
35 584 arousal are sorely needed if we are to change this situation, so that we can make  
36 585 and test differential predictions for patterns of behaviour that would be primarily  
37 586 arousal driven or intentionally driven. This is not to say that these options are  
38 587 mutually exclusive; in fact it is likely that arousal plays a complementary role to  
39 588 intentional processes, as it does in humans, but we need to try and disentangle the  
40 589 relative contribution of affective arousal and higher cognitive processes on  
41 590 communicative behaviour.

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48 591 Technological advances allowing us to test signaller arousal, as well as  
49 592 finding that more distantly related species are meeting criteria for first order  
50 593 intentionality (e.g. fruit fly courtship behaviour; Shuker, personal communication),  
51 594 may lead us to conclude that the behavioural criteria for first-order intentionality are  
52 595 not particularly useful for informing understanding of language evolution. In that  
53 596 eventuality, we may have to reconsider the virtues of trying to find evidence of  
54 597 second-order intentional signal production in non-human species. Despite its  
55 598 disadvantages (12), it may be the best approach we have left. As second-order

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3 599 intentional signal production builds on first-order intentional processes (voluntary  
4 600 goal-directed signal production), if second-order communication is demonstrated,  
5 601 this also provides evidence for first-order intentionality, but bypassing the need to  
6 602 rely on criteria with questionable validity. Second-order intentional signal production  
7 603 requires attribution of mental states, and this has been most commonly tackled by  
8 604 looking to see if signal production is mediated by the knowledge state of the  
9 605 recipient. This is a promising approach, at least in chimpanzees, as there is  
10 606 convergent evidence from a number of paradigms that chimpanzees understand  
11 607 what other chimpanzees have seen and know (44, but see 45) and it is clear that  
12 608 such theory of mind skills are necessary for second-order intentional signal  
13 609 production (35). Whether the understanding of others' mental states influences  
14 610 signal production is still currently unclear: it has been claimed that chimpanzees are  
15 611 more likely to alarm call in the presence of individuals that have partial knowledge  
16 612 rather than full knowledge of a model snake (16), but it is not clear that lower level  
17 613 behaviour reading explanations have been excluded (47).

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19 614 What is clear is that further investigations focussed on whether signal  
20 615 production is mediated by an understanding of others' knowledge or ignorance are  
21 616 likely to focus on the vocal domain. There is good evidence that vocalisations  
22 617 function to refer to external objects and events, so it is possible to probe whether  
23 618 these calls are influenced by receivers' knowledge of those objects or events. In  
24 619 contrast, gestures to conspecifics seem to have less potential to be influenced by  
25 620 knowledge of mental states, as they are predominantly dyadic requests for certain  
26 621 behaviours from another individual (e.g. give me X; do X; stop that; come here;  
27 622 (20,21)). There are only a handful of potential cases of triadic gestures that have  
28 623 ever been observed in wild chimpanzees or bonobos, in many decades of continual  
29 624 field observations (56,57). In captivity many apes will point for human caretakers, but  
30 625 these points still seem to share the same imperative motivation as their naturally  
31 626 occurring gestures, in that they point to request things that they want, but do not  
32 627 gesture with an informative intention (58), where experimental manipulations of  
33 628 receiver knowledge could be usefully deployed. Thus, future investigations of  
34 629 second-order intentional signal production are likely to focus on whether the  
35 630 knowledge state of listeners mediates the production of functionally referential vocal  
36 631 signals. And as regards current debates, independently of whether or not it is best to  
37 632 take a Gricean approach to intentionality (10,11), testing second-order intentionality

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3 633 in great apes has the potential to inform us about their capacity for meta-  
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5 634 representation and contribute more broadly to the field of animal cognition.  
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8 636 In conclusion, in order to further our understanding of language evolution it is  
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10 637 vital that we move beyond surface similarities between human language and primate  
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12 638 communication, and search for commonalities and differences in the cognitive  
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14 639 processes driving the production and reception of signals. The degree of intentional  
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16 640 control in non-human signal production is a central and important question, and  
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18 641 although first-order intentional communication has been widely claimed, the current  
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20 642 tools we have to detect intentional signal production are limited. The validity of the  
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22 643 behavioural criteria for distinguishing first-order from zero-order intentional signal  
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24 644 production is questionable and inconsistency across studies in how and which  
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26 645 intentionality criteria are applied limits comparability. Looking ahead, we need to be  
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28 646 able to detect first-order intentional communication with greater accuracy to  
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30 647 understand how widespread it is in the animal kingdom and what selection pressures  
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32 648 facilitated the evolution of this type of communication. The development of  
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34 649 physiologically validated behavioural measures of arousal is essential if we are to  
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36 650 truly understand the relative contribution of zero-order and first-order intentional  
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38 651 processes to signal production in non-human species. Until those tools are available,  
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40 652 however, productive steps may include individual researchers explicitly  
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42 653 acknowledging the zero-order alternatives to the first-order behavioural markers they  
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44 654 use, and a renewed focus on second-order intentionality in vocalisations produced  
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46 655 by species with established Theory of Mind skills (35).  
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For Review Only

Table 1. Studies examining intentional signal production in non-human primates. Papers selected for relevancy from an initial search for 'intentional communication' & 'primate' on Web of Science that were published in journal articles from 1980-2018.

Paper Details		Intentionality Criteria used	Empirical details				
Author	Year		Criteria explicitly tested with data	A priori criteria signals met to be classed as intentional	Order of intentionality claimed	Type of signal	Species
Bard	1992	Social use	No	N/A	First	Gestural	Bornean orangutan
Brockett et al.	2004	Goal-directed	No	1/1	First	Gestural	Black howler monkey
Cartmill & Byrne	2010	Social use, Gaze alternation, Persistence, Elaboration, Flexible use, Response-waiting	No	Not specified	First	Gestural	Bornean & Sumatran orangutans
Crockford et al.	2012	Calling behaviour modified when audience is ignorant vs knowledgeable of predator	Yes	N/A	Second	Vocal	Eastern chimpanzee
Demuru et al.	2015	Social use, Attentional state [secondary = eye contact, body orientation, response waiting, persistence]	No	Not specified	First	Gestural, Facial	Bonobo
Fröhlich et al.	2016	Attentional state, Response waiting, Persistence, Satisfaction with goal	No	Not specified	First	Gestural	Eastern & Western chimpanzees
Fröhlich et al.	2018	Audience checking, Attentional state, Persistence	No	N/A	First	Gestural, Vocal	Eastern & Western chimpanzees

Genty & Byrne	2010	Social use, Attentional state, Persistence, Elaboration	No	Not specified	First	Gestural	Western gorilla
Genty et al.	2009	Social use, Attentional state, Attention-getters, Persistence, Elaboration, Flexible use, Response-waiting	No	3/3	First	Gestural	Western gorilla
Gruber & Zuberbühler	2013	Social use, "Checking" (Attentional state), Persistence, Response-waiting	Yes	N/A	First	Vocal	Eastern chimpanzee
Graham et al.	2018	Attentional state (audience checking), Persistence, Response-waiting	No	1/3	First	Gestural	Bonobo, Eastern chimpanzee
Gupta & Sinha	2016	Persistence	No	1/1	First	Gestural	Bonnet macaque
Halina et al.	2013	Persistence, Satisfaction with goal	No	2/2	First	Gestural	Bonobo
Hobaiter & Byrne	2011a	Social use, Attentional state, Persistence, Flexible use, Response-waiting	No	1/4	First	Gestural	Eastern chimpanzee
Hobaiter & Byrne	2011b	Social use, Attentional state, Attention-getters, Persistence, Elaboration, Response-waiting	No	1/4	First	Gestural	Eastern chimpanzee
Liebal et al.	2004	Social use, Attentional state, Attention-getters, Persistence, Elaboration, Flexible use	No	2/2	First	Gestural, Vocal, Facial	Chimpanzee
Liebal et al.	2004	Social use, Attentional state, Persistence, Elaboration, Flexible use, Response-waiting	No	2/2	First	Gestural, Facial	Siamang
Liebal et al.	2006	Social use, Attentional state, Persistence, Elaboration, Flexible use, Response-waiting	No	2/2	First	Gestural, Facial	Sumatran orangutan

1	Roberts et al.	2013	Attentional state	No	1/1	First	Gestural	Eastern chimpanzee
2	Scheel & Edwards	2012	Goal-directed	No	1/1	First	Gestural	Spider monkey
3	Schel et al.	2013	Social use, Gaze alternation, Attentional state (specifically audience checking), Persistence	Yes	N/A	Zero & first	Vocal	Eastern chimpanzee
4	Sueur & Petit	2010	Flexible use, Goal-directed	Yes	N/A	First	Body posture/ movements	Tonkean & rhesus macaques
5	Tempelmann & Liebal	2012	Social use, Attentional state, Attention-getters, Persistence, Elaboration	No	1/1	First	Gestural	Orangutan
6	Tomasello et al.	1985	Social use, Gaze alternation, Response-waiting	No	1/3	First	Gestural	Chimpanzee
7	Tomasello et al.	1994	Social use, Gaze alternation, Attentional state, Attention-getters, Persistence, Elaboration, Flexible use, Response-waiting	No	Not specified	First	Gestural	Chimpanzee
8	Waller et al.	2015	Attentional state	No	1/1	First	Facial	Orangutan