Communication Functions in Speech Board Use by a Goffin's Cockatoo: Implications for Research and Design

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Abstract

This study investigates the potential for parrots to engage in functional communication using speech board interfaces. We examine whether the interactions of a Goffin's cockatoo with her speech board correspond to established functions of communication identified by Jakobson's linguistic model and whether there is correspondence with biological functions in animal communication. Additionally, to explore the bird's intentionality we examine her persistence in making requests via speech board selections, her ability to seek out displaced representations of preferred foods, and her response to unexpected outcomes. Our findings suggest that the cockatoo's interactions with the speech board align with established linguistic and biological communication functions and indicate intentional communication on her part. This has implications for studying parrot cognition and, thus, for designing speech board interfaces that might better support parrots' communication abilities.

CCS Concepts

• **Human-centered computing** → Interaction design; Interaction design process and methods; User centered design; • **Additional Keywords and Phrases: Animal-Computer Interactions, Speech Board Interactions, Parrot Communication**;

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1 Introduction

Interactive technologies are playing an increasing role in the management of animals under human care. Typically, the aim is to enrich animals' life experiences by providing them with opportunities to undertake stimulating activities [12], [35], [38], [16], [85], attain greater control over their surroundings [7], [76], or potentially express themselves [13]. As a case in point, in recent years, a considerable amount of Animal-Computer Interaction (ACI) research has focused on parrots' use of screen-based applications such as video-conferencing, allowing the birds to remotely interact with their conspecifics [36], and AAC (Augmentative and Alternative Communication) devices, enabling them to produce a wide range of utterances using representations such as sound-text correspondences [15] and tools such as speech boards [13], [14]. These interactions have prompted considerations of how technology could be developed to enhance these experiences [35].

In particular, speech boards, which are extensively used for AAC with humans who have limited speech or language skills [31], have been adapted for use with parrots with the aims of both enrichment and expression, potentially enabling them to communicate with humans [13]. Typically, the device interfaces feature a series of menus from which the birds can select (by pressing them with their beak) representations displayed on the screen, whose meaning they have acquired via associative learning during positive reinforcement training [40], [13] (these may be pictures of varying levels of abstraction, from drawings to photos, or abstract shapes [47]). These representations might signify nouns identifying objects in the animal's environment (e.g. foods, toys) or other members of the household (e.g. caregivers, other birds); qualifiers identifying sensory perceptions (e.g. hot, cold, fast, slow) or experiences and possible emotions (e.g. happy, afraid); verbs identifying subjective assessment (e.g. like, no-like), volitional states (e.g. want, no-want), or actions (e.g. walk, run). By navigating the menus, the birds can make sequential selections, thus composing simple utterances (e.g. like warm). Upon each selection, the system produces the corresponding word.

A key question that researchers are still exploring is whether these devices, with the interaction modality that they afford and the representations that they provide, can indeed enable parrots to communicate. To begin to explore this question, researchers have investigated alternative explanations. Specifically, recent studies [13] have compared data resulting from the speech board interactions of a single cockatoo, Ellie, with data produced by different simulation models, finding that simulated data significantly diverged from observed data, suggesting that Ellie's interaction was

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not random. This raises the question as to what else might be at play in Ellie's interaction with the speech board. Could she be intentionally making different selections to communicate? If Ellie and parrots like her are indeed able to engage in functional communication via devices such as speech boards, how should their interface be designed to best support them in their communication activities? Conversely, what interface designs could help us determine with some certainty whether and to what extent parrots are able to engage in functional communication?

As a step toward answering these questions, we examine Ellie's interactions with her speech board through a double lens: from the perspective of the biological functions that communication has in the animal kingdom in general and in parrots in particular [24], [6]; and from the perspective of communication functions, as identified by Jakobson's model [32], [84]. For this study, we analysed the following types of interactions previously recorded over three months and encompassing over 2,600 selections representing food and beverages (e.g. seeds, fruit), activities (e.g. tablet games, books, music), emotions (e.g. happy, sad), and perceptions (e.g. temperature). Additionally, to probe the extent of Ellie's intentionality, we assessed her persistence in making requests when these were not being fulfilled (477 trials). To help validate her intentionality, we also introduced new tasks that would disrupt potential automatic interaction patterns acquired through conditioning. These tasks probed Ellie's engagement in seeking representations that had been randomly rearranged (30 trials) and her response to unexpected selection outcomes when her requests were fulfilled incorrectly (9 trials). These trials included offering unwanted foods, such as broccoli in response to a selection for a sunflower seed; or alternatively a similarly valued treat, such as an apple in response to a selection for a seed ball. Trials also included offering alternative enrichment activities, such as a tablet game different from the one she selected, or a book instead of a tablet game.

We present both quantitative results and qualitative descriptions illustrating specific episodes. Overall, our findings suggest that the utterances resulting from Ellie's use of the speech board have correspondence with specific linguistic communication functions in Jakobson's model and that they are consistent with biological communication functions relevant to her circumstances. Findings regarding her persistence and seeking behaviour and her response to incorrect fulfilment of requests suggest that her engagement with the speech board is both intentional and functional. We discuss the potential significance of these findings for understanding parrots' ability to engage in functional communication, as well as implications for the design of speech board interfaces that could optimally support their communication activities.

2 BACKGROUND

2.1 Animal Communication and its Biological Functions

Sensemaking and communication play a fundamental role in the life of any animal. According to [51], just as animals acquire and process resources from the environment and then release waste, so they acquire and process information from their surroundings and then act upon it to support a range of biological functions important for their survival and reproduction. Such functions include:

2.1.1 Mating and Reproduction. Since evolution selects for organisms that reproduce, many animals [27] have developed signalling systems for attracting mates by conveying their readiness and fitness to potential mates and by warding off competitors. For example, female baboons' rumps swell and blush when they are ovulating and male peacock jumping spiders raise their abdomen in a colorful display to charm females during courtship. Budgerigars seek out partners who have similar sounding contact calls to find a mate [52], even in captivity [24].

2.1.2 Territorial Claims. Territory is essential for subsistence and reproduction, and many animals use a range of olfactory and acoustic signals to establish and maintain territorial boundaries and thus secure access to resources, find mates, and raise young [86], [11]. For example, canids, such as wolves and wild dogs, and felids, such as lions, advertise their presence by marking objects with urine and by vocalising [1], [69], [29]. Birds have also been shown to use vocalizations to defend their territory [20], [6], [5]; this includes parrots who have been found to have specific calls to indicate territoriality [6], [37].

2.1.3 Navigation and Migration. For animals who are nomadic or who migrate between territories, such as some birds, whales or elephants, communication is essential to aid navigation and maintain social cohesion during journeys and across distances. For example, elephants emit low-frequency vocalisations that humans cannot hear (infrasound) to coordinate the herd's movements or to find group members [58], [25], [42]; geese produce honking sounds to ensure flock members don't fall behind and to maintain V-formations in flight [72]; and parrots use contact calls to identify the location of other flock members [4].

2.1.4 Alarms and Warnings. Whether stationary or in transition, safety is a primary concern, so communicating danger by issuing alarms is pervasive in social animals [10], [30]. Alarm calls prompt defensive responses from other group members, enhancing their collective safety. Callers often signal precise warnings to conspecifics, often based on the type and level of urgency of the danger [49]. For example, prairie dogs produce alarm calls that provide colony members detailed information about the impending threat [34]. Elephants use infrasound to signal alarms across long distances [58]. Parrots, too, use alarm calls to alert other flock members to possible predators [6].

2.1.5 Food Discovery and Sharing. After safety, the acquisition of resources is a key priority and, in this regard, communication is particularly important in social animals. For example, honeybees perform complex waggle dances to share with members of their hive the distance and direction of the location of food sources and suitable nest sites [74]; ants use pheromones to communicate food locations [17]; and crows' vocalizations can specify to others the presence and quantity of food, as well as request food from family members [53].

2.1.6 Social Bonding and Caretaking. Beyond mating, territory, safety, and resources, communication among conspecifics is important for many animals, including mammals and birds, to help them form and maintain social bonds and cohesion by appropriately managing interactions and successfully negotiating group dynamics [56], [23].

2.1.7 Raising Young. A particular social interaction in which communication plays a crucial role is that between parents and their offspring, when effective communication ensures that parents can protect, nourish, and teach their young. For instance, baby birds vocalize to request food [33] and emit distress calls [44], while parental alarm calls result in behavior changes in their offspring; in horses, effective mare-to-foal communication impacts foal survival outcomes [54]. Parrot offspring develop contact calls and learn to discriminate between members of their own flock and other flocks from an early age [6], [3].

In sum, across the animal kingdom, communication supports fundamental biological functions, helping to ensure individual and group survival, and contributing to the reproductive success of species through complex and often sophisticated behavioral strategies.

2.2 Intentionality and Parrot Communication

In basic terms, communication usually involves the intentional transmission of information from a sender to a receiver conveyed by a range of signals, usually with the aim and often with the result of altering the behaviour of the latter [71], [73], [75]. Communication may also be unintentional on the part of the sender, where information is transmitted by involuntary clues (e.g. human facial expressions or body language, the noise made by squirrels as they dig) that the receiver is able to interpret. Demonstrating intention, however, can be difficult. But even though intentionality is difficult to demonstrate, taking a functional approach (whereby others assumed to possess information which they use to pursue certain goals) and responding as if behaviors were intentional may help predict and interpret what animals do (regardless of their assumed level of consciousness) [21], [22]. To address the issue of intentionality in communication, many researchers have proposed frameworks, including Mocha & Burkart [2], who suggest a multistage process for assessing intentional signalling. One of these stages includes assessing voluntary control in signalling behaviour and can be demonstrated, for example, by an animal's signalling persistence until a communication goal (e.g. obtaining food from a parent) is either achieved or abandoned due to a clear failure to achieve it [2]. Animal communication is highly dependent on contextual sensory experience and may occur via visual (e.g. body postures and displays, markings), acoustic (e.g. song, percussion), tactile (e.g. bodily contact), olfactory, or gustatory (e.g. pheromone in fluid deposits) signals [75], [71]. Additionally, human communication, in particular, largely occurs via a highly symbolic signalling system and can permit the transmission of information independent of contextual sensory experience. In the past, these perceived differences between human and animal communication and cognition led researchers to underestimate the complexities of animal communication (see, for example, the discussion in [66]). Recent work is increasingly highlighting its complexity and the need for additional research [64], [9], [63], [57].

Birds are complex communicators with a large repertoire of signaling behaviors including socially learned vocalizations and visual displays [6], [4], [45]. These vocalizations indicate intention; for example, alarm calls may vary based on experience and on the type of predator [78], [28]. During sensitive activities (e.g. courtship), interlocutors modulate the volume of their songs depending on whether other conspecifics are present in order to control who has access to the information conveyed by their vocal signals [18]. Some birds combine calls in a way that suggests simple syntactic pattern recognition, as the order in which the sender chains call segments significantly affects the response of the receiver, suggesting a level of semantic discrimination based on syntactic variations [79], [26]. A common signal across many species of birds that could indicate an intention to deceive a predator is to feign a broken wing to lure predators away from the nest, only to then fly away at the last minute [19]. An even more complex use of body language in birds is provided by the Japanese tit, who seemingly produces a wing-fluttering gesture to invite their mated partner to enter the nest first, akin to the meaning 'after you' [80].

Parrots, in particular, use a wide variety of body signals and vocalizations, providing layers of nuance to their complex communicative behavior. Body signals include wing behaviour (e.g. flapping, flipping, drooping), feather behaviour (e.g. ruffling, quivering, raising), tail behaviour (e.g. wagging, bobbing, fanning), feet behaviour (e.g. tapping, scratching), beak behaviour (e.g. grinding, clicking, chewing, mouthing), head behaviour (e.g. shaking, bobbing), and general postures (e.g. attention position, bowing, crouching). Additionally, parrots have remarkable vocal skills and express a great variety of signalling behaviours, including chattering, purring, growling, tongue-clicking, singing, whistling and even talking. They employ this great variety of signals to convey emotion and pursue biological goals, such as engaging in mating, warning against predators, or coordinating social activities. One of a small group of vocal learners (i.e. animals who learn vocalizations from others), parrots can reproduce, but also appear to learn, the meaning of human speech through associative learning. For instance, Alex, an African grey parrot, acquired over 170 English words, referring to over 50 objects and their shapes, colors, categories, and quantities, and learnt to use them in the correct contexts [62], [60]).

The aspects of parrot communication, from their intraspecies signaling to their interspecies vocal plasticity [59], suggest a level of cognitive processing that rivals that of primates [65], [68], and human children [61], in some cases outperforming five-year-old children and performing with accuracy comparable to adults (Harvard students) [67]. Advances in cognitive science have shown that corvids and parrots have more densely packed neurons in their brains compared to other birds and some primates, indicating high levels of cognitive ability [55]. These findings have led researchers to hypothesize that parrots, after acquiring associations with representations relevant to their environment, might be able to learn to intentionally and meaningfully engage in exchanges with their caregivers. The decades of study on the abilities of parrots to acquire associations suggest that these birds could indeed learn to engage in meaningful exchanges, provided that they had at their disposal a repertoire of relevant representations with shared associations and a medium that allowed easy access and selection of those options. In the wild, parrots engage with their natural environment and seek opportunities for functioning optimally. All the while, they are under pressure to survive environmental challenges, including predators and other safety hazards. In contrast, in captive environments, while parrots do not need to be concerned as much with predators and environmental safety, they face a different set of challenges. Captive environments often lack the types of stimulation their natural environment would provide and tend to be monotonous and overly predictable [77]. Moreover, captive parrots lack the opportunity to engage in intentional communication, as they would in the wild with other parrots. However, providing captive animals with varied and plentiful social, environmental, physical, and cognitive enrichment opportunities, as appropriate to their species, is essential for their well being and health, and to ensure that they do not develop abnormal, often repetitive behaviors known as stereotypies [53]. Stereotypic behaviors can indicate a range of health and well being issues and can even impair brain function over time [81]. Enrichment activities provide animals with stimulation, and even the opportunity to express their agency, by making choices and exerting a measure of control over their environment, which can significantly improve their well being [83], [77]. Providing parrots with meaningful challenges that can substitute for their natural activities can allow them to express agency, make choices, and exert control, and thus help to compensate for the shortcomings of the environment in which they live. Although, for caregivers of captive parrots, it may be difficult to know what their birds want or need at any given time, one way to afford their birds agency and control over their environment is via the use of a speech board: once the parrots have demonstrated acquisition (through associative learning) of the association between different representations and their respective meaning, the caregiver can allow their bird to make selections, give them what they select, and watch for continued indications of corroboration as expressed by their engagement or by the duration of the interaction with the objects or activities corresponding to the selected representations.

2.3 Speech Board Use with Parrots

Extensively used for AAC with humans who have limited speech or language skills [31], speech boards originated with Rumbaugh's work with Lana, a chimpanzee. This work was incorporated into use by humans with complex communication needs. It has been additionally adapted for use with other animals, including parrots, as a form of enrichment and to provide them with a means of expression across the interspecies communication barrier, to deliver both social and cognitive benefits for companion animals and their owners. However, the validity of these interactions has been questioned due to the difficulty of ascertaining whether the animals are capable of cognitive engagement with such devices and of meaningfully participating in the exchanges for which they are designed [13].

Despite this difficulty, the use of speech boards, both in and out of laboratory settings, has produced intriguing findings. Examples include a cockatoo operating a communication board on a touchscreen [14] [13]. Interfaces of these devices can be adapted to present a variety of representations of objects, activities and possible experiences relevant to parrots' own contexts and preferences. Specifically, Ellie the cockatoo was successfully trained to interact with a speech board featuring several menus comprising different categories of relevant options (e.g. food treats, books). By touching the screen with her tongue, she could open menus and sub-menus down to 5 levels, and select any of the options within, to perform a range of communicative tasks (e.g. select a book for enrichment or select an apple to eat) [14]. Ellie was taught the shared meaning of these representations on her speech board by leveraging associative learning through positive reinforcement and appeared to be proficient in their use. To investigate the extent to which Ellie's interaction with the speech board might evidence intentionality, and thus effective communication, a recent study [13] compared data resulting from her speech board interactions with data produced by different simulation models, finding that simulated data significantly diverged from observed data: her selection patterns were not random and, although they were slightly biased by the arrangement of menus on the screen (e.g. higher probability that items in the top-left corner of the screen be selected more frequently), even interface design biases could not account for her interaction patterns. The authors concluded that intentionality might explain Ellie's interaction but that further investigations would be needed to ascertain this.

As a step towards exploring whether Ellie might be intentionally selecting different representations to communicate, we use Jakobson's functional communication model as a framework to examine the communication functions that her 'utterances' appeared to have, and to assess how these apparent functions might map onto the biological functions of animal communication, given Ellie's environmental conditions.

2.4 Functional Communication Theory

Over the past decades, various theories have been developed to model the functions of communication. In this regard, one of the earliest models was developed by Harold Lasswell [39], in the 1940s, whose famous definition "Who says what, in which channel, to whom, with what effect?" focused on the function of conveying content, the method used, the target audience, and the effect achieved. (This model laid the groundwork for later developments in research focusing on influence and persuasion.) Over time, other models have been proposed, which variously built on Lasswell's work, including Bühler's organon model of functional communication, according to which, language had an expressive function (e.g. expressing one's feelings), a representation function (e.g. describing observed phenomena) and a conative or appealing function (e.g. appealing to someone to ask for help) [8].

In the 1960s, Roman Jakobson expanded Bühler's model of functional communication to better describe the functions of the act of communication [32]. His model identified six primary communication functions:

- Phatic: Communication that establishes or maintains social relationships
- Emotive: Communication that conveys feelings, desires, and moods
- Conative: Communication that aims to induce a behavior change in the receiver of the message
- Referential: Communication that objectively shares information such as observations

- Poetic: Aesthetic communication, focusing not only on the message, but also on the way in which it is transmitted
- Metalingual: Communication about language itself, such as word definitions, clarifications of ambiguous messages, and word play.

As discussed above, in many species, animal communication has a wide range of specific functions. These might include, for example, conative functions (e.g. asking for food), emotive functions (e.g. expressing distress), phatic functions (e.g. prolonging a social interaction), referential functions (e.g. describing the location of food), or poetic (e.g. singing to attract mates). The question we wanted to explore was whether a cockatoo's selections on a speech board might have correspondence with any functions of linguistic communication. Our aim was to explore the possibility of bridging the gap between speech-board-mediated functional communication in parrots and language-mediated functional communication in humans, leveraging a model widely adapted to analyzing the latter.

For this, we drew upon Jakobson's model, because: 1) its focus on the functions of linguistic communication, rather than on its forms, allowed us to apply it to a communication system that was different from natural language (i.e. the representations in the menus and sub-menus provided by the speech board); 2) the functions that the model identifies are abstract enough to present (with the exception of the metalingual and poetic functions) striking correspondence with fundamental biological functions of communication in nonhuman animals. Indeed, Jakobson himself makes direct reference to birds using phatic communication in his theory, stating that talking birds speak to prolong the interaction and share this function with humans [32].

Although developed in the mid-19th century, Jakobson's model focuses on the social and structural aspects of communication, emphasizing how messages are constructed and understood within various contexts. Thanks to these characteristics, the model is still widely utilized by educators to understand the communicative goals of learners [82], as well as by linguistics and communication researchers in analyzing how language operates in different contexts (e.g. in packaging messages [43], in movies [41]).

3 METHODOLOGY

3.1 Participant

The sole participant in this study is Ellie, a female Goffin's cockatoo. The cockatoo has lived with her caregiver since she was 14-weeksold and is housed with two other cockatoos in a 7.3m x 7.3m indoor aviary with an adjacent 6m x 6m outdoor aviary. The housing environment includes naturalistic foraging opportunities as well as a variety of other enrichment opportunities including a rotating supply of parrot toys and a speech board. Other caregivers are trained to maintain the same schedule and level of interaction. All caregivers interact with Ellie using both tablet and non-tablet activities including playing together with toys, reading books, dancing to music, playing in the outdoor aviary, or going for walks.

3.2 Research Ethics

Because Ellie is a companion animal living with her caregiver, ethical approval requirements were waived by Purdue University. However, at all stages, the study protocol and our engagement with the bird was consistent with the principles of relevance, impartiality, welfare and consent (both mediated and contingent) underpinning the animal-centred research and design frameworks previously proposed for ACI research [46], [48], [70]. Although the first author of this paper is the primary caregiver of the parrot, during research activities every effort was made to maintain neutrality in the participant-researcher interaction.

3.3 Data Collection and Training

Our team is building on prior work done in this area, including using the same data set from the same parrot, a detailed description of which may be found in [13]. The original method to train Ellie leveraged associative learning through operant conditioning (using positive reinforcement) to teach her the meaning of 200+ representations over a period of more than 10 years. In [13], the authors examined pre-existing video data over a seven-month period during which the parrot made over 5,000 selections. The data were analyzed for randomness, corroboration behavior, and enrichment potential. Because the results of this recent work indicate that the selections may not be explained by randomness alone, our team utilized portions of the existing data set to examine Ellie's selections under the lens of Jakobson's [32] Functions of Communication Model. Firstly, we wanted to see if the parrot potentially used the speech board for similar functions to those in Jakobson's model. Secondly, we wanted to see if the categories of those possible functions could be similarly aligned to the biological functions of parrot communication.

In addition, we examined two new areas here: firstly, within the existing data set we sought to assess whether, and in which contexts, the cockatoo persisted with unfulfilled requests, possibly indicating intentionality; secondly, we ran new trials to look at whether changing the arrangement of representations on the speech board would prompt the parrot to seek wanted items in new places, and whether the delivery of items that did not match the parrot's selections would result in her refusing the incorrect item. An example of the speech board interface is included as Figure 1.

3.4 Categorization of Functions

To explore the possibility of the parrot's selections being explained by goal-directed behavior, two members of the research team independently coded the speech board selections at both the menu and sub-menu levels using Jakobson's categories. To do this, we defined the categories in the context of the caregiver's regular usage with the parrot. For example, if Ellie entered a 'Treats' menu and, within it, selected a representation for 'sunflower seed', which she then consumed, the interaction was viewed as conative due to the observation that this seemed to be a request for the treat. We acknowledge that even Jakobson mentioned the likelihood that any utterance could correspond to multiple categories, and when coding, we selected what we believed to be the primary category. After all interactions were coded for the functions, the researchers then coded all the conative function items to be one of three categories

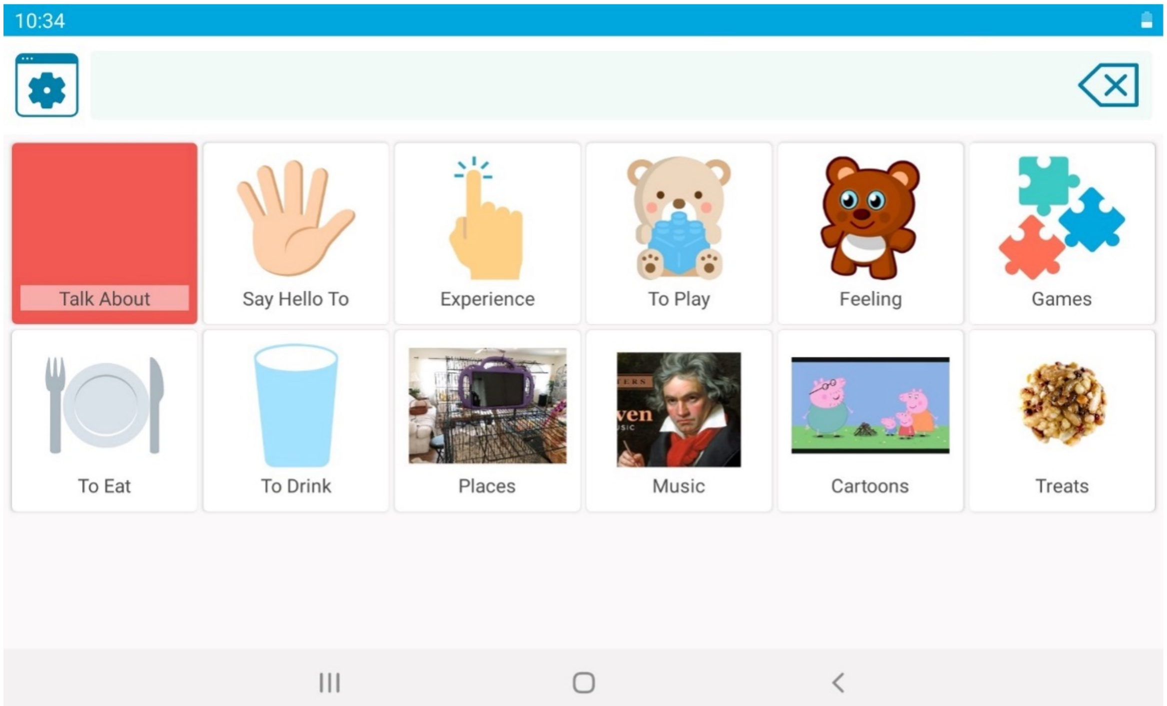

Figure 1: An example of the AAC system, this one is with the Main Menu.

emerging from the data: food/beverage (requests for food or drink), social (requests for social interactions), or enrichment (requests for enriching activities).

3.5 Persistence Behavior

As mentioned above, one function of communication for a signaler is to change the behavior of a receiver, and when this occurs, the need to send a signal ceases. To explore whether Ellie's selections might constitute communication exchanges, we examined a subset of the already existing dataset in which the parrot's selections corresponded to specific 'requests' for items or activities. We analysed the parrot's persistence behavior when her selections were not immediately fulfilled, to see how many times she continued to select the same representation before the corresponding item or activity was delivered, or she abandoned the selection. In particular, we considered:

- persistence within the same session how many times, during one session with the speech board, she selected the same representation (e.g. 'sunflower seed') again after her initial selection went unfulfilled or was refused: P1 = 1 additional selection; P2 = 2 additional selections; or P3 = 3 or more additional selections.
- persistence within the same menu whether she continued to select the same representation (e.g. 'sunflower seed') or a different selection in the same menu (e.g. a different treat in the same 'treat' menu) after a refusal or lack of fulfilment by the caregiver. This was similarly defined as P1, P2, and P3, except any item she selected on the menu was counted as a request.
- corroboration with selections if she persistently selected a food item that had been repeatedly denied, once that item was finally offered, how many times she consumed at least three bites; or, for a persistently selected but repeatedly denied activity, how many times, once that activity was finally offered, she engaged in it for at least one minute [13].

3.6 Seeking Behavior

To assess the parrot's understanding of the association between the selection and the outcome and whether she might seek representations that corresponded to favored foods (regardless of their placement), we developed a 'treat game' menu on the main screen of her speech board (See Figure 2). This menu featured representations of six different food items, three that she often consumed as treats (sunflower seed, nut, cheese), and two that she did not usually consume (water and broccoli). We wanted to see if, despite variations in the placement of the options, 1) a selection pattern might emerge whereby she consistently selected her preferred food items; 2) to what extent she would corroborate her selections by consuming the items; and 3) her ability to find a representation when the placement kept changing.

The test comprised thirty trials, and we used a random number generator to randomize the placement of the representations within the menu for each trial. The caregiver showed Ellie the location of the 'treat' menu and trained her to associate each representation with the corresponding outcome 3 associations for options with

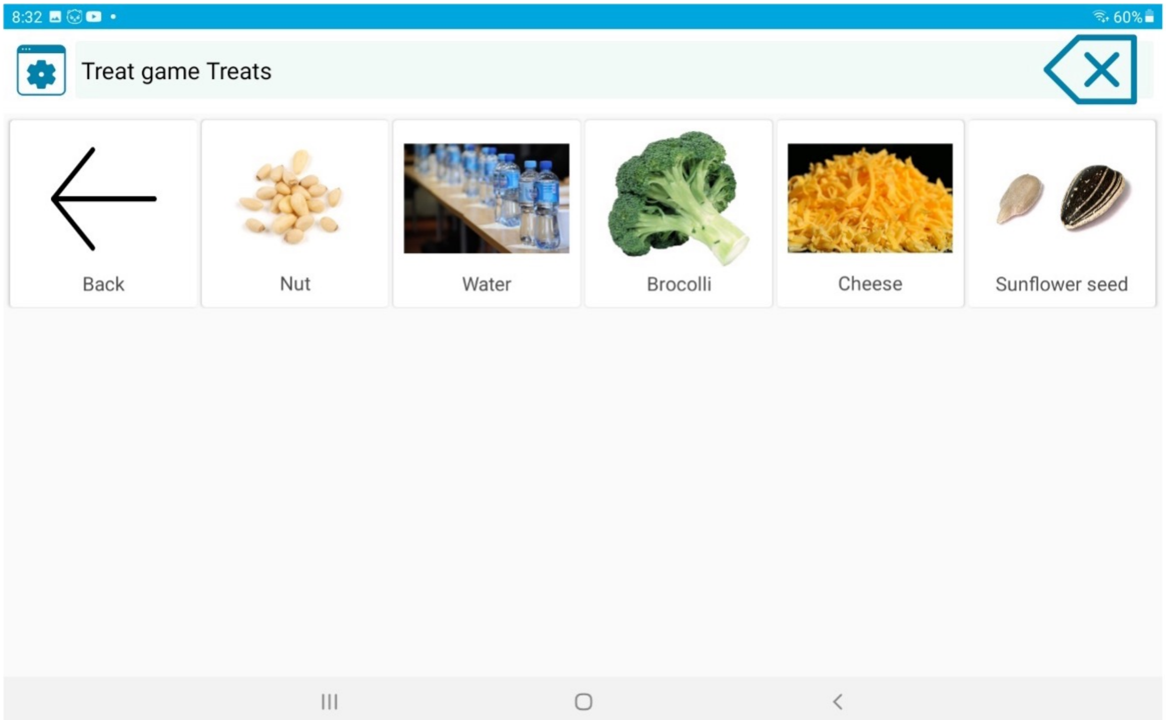

Figure 2: The "Treat Game" test menu on the AAC device. If the parrot selected "Treat Game" the speech board opened to this menu.

which she was already familiar (sunflower seed, nut, water), and 5 associations with new options (cheese, broccoli). During the trials, the caregiver turned her back to the parrot as a visual shield to avoid unintentionally cuing her, thus blinding herself to what the parrot was doing. Whichever selection the parrot pressed first was logged.

3.7 Wrong Fulfillment Behavior

To explore whether Ellie would be discerning about the outcome of selections she made or whether she would undiscerningly engage with activities or ingest food items offered, we conducted a 'wrong fulfillment' test. This involved giving her items that did not correspond to her selections to see how she responded. The test involved items with which Ellie was already familiar and which did not require training. We made the following kinds of substitution, with the same corroboration requirements described above [13]:

- with a food item of a similar value (the parrot would need to take 3 bites or ingest the entire thing)
- with a food item of a lower value (the parrot would need to take 3 bites or ingest the entire thing)
- with a play or social activity (the parrot would need to engage with the activity for at least 1 minute or permit the social activity)

We ran 9 trials, during which we offered incorrect items from each of the above categories.

4 FINDINGS

To explore the potential for intentionality and communication in Ellie's selections, we analyzed these within the context of Jakobson's Model of Communication. As discussed above, to probe the extent of Ellie's intentionality, we assessed her persistence in making requests when these were not being fulfilled (477 trials). We also introduced new tasks that would disrupt potential automatic interaction patterns acquired through conditioning. These tasks probed her engagement in seeking representations that had been deliberately displaced (30 trials), and her response to unexpected selection outcomes when her requests were fulfilled incorrectly (9 trials). Next, we analyze the results.

4.1 Results from Communication Functions Analysis

According to Jakobson's model, the largest proportion of Ellie's selections had a conative function (63.6% of the times); a smaller proportion had an emotive function (25.2% of the times), and an even smaller proportion had a phatic function (10.7% of the times); while a very small number of selections had a referential function (.5%) as seen in Figure 3. Of the selections that had conative function, 53% were requests for cognitive enrichment (e.g. mental challenges) or environmental enrichment (e.g. outdoor activities); 30.8% were requests for social interaction (with no other associated activity); and 15.11% were requests for food, beverage or treats

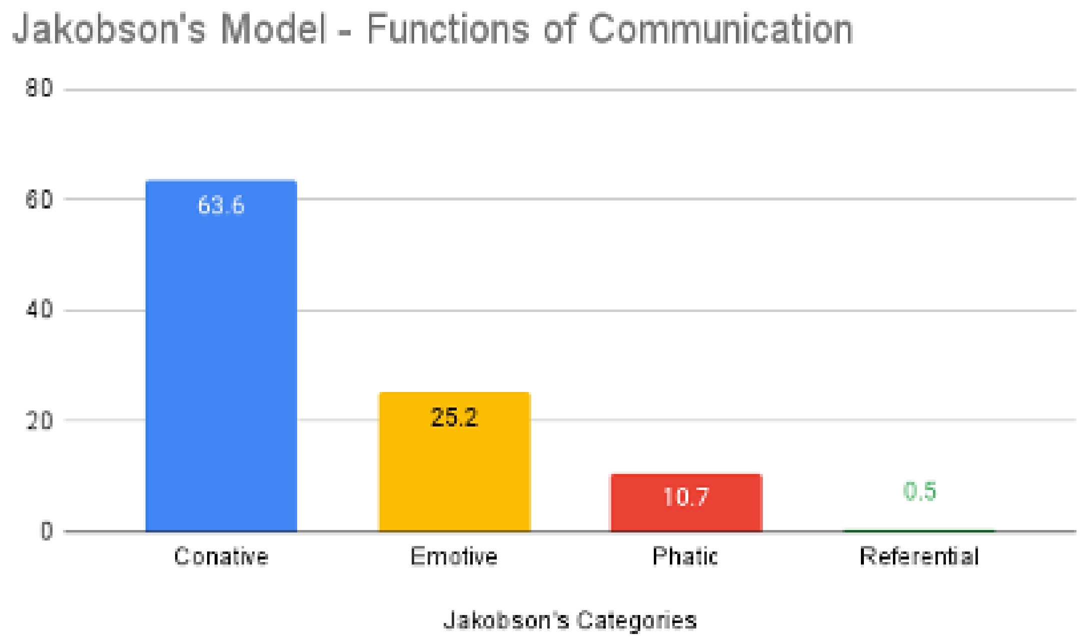

Figure 3: The parrot's selections as categorized in Jakobson's Functions of Communication.

(Figure 4). Below are qualitative descriptions of examples of requests for an environmental enrichment activity and for a social interaction respectively.

4.1.1 Qualitative Example Descriptions. Example 1 - As the caregiver greets the two other resident birds in the room, Ellie positions herself in front of the speech board, which displays the main menu. She selects the representation for 'say hello to', which opens the related sub-menu. Of the 12 options available in the sub-menu, Ellie repeatedly selects the representation for 'mom' (a picture of her main caregiver) and, then in rapid succession, 'car ride' (a drawing of a car), followed by 'Cori' (a picture of an occasional caregiver of hers). Then she repeatedly selects 'car ride' again and, in rapid succession, she again repeatedly selects 'mom', followed by 'outside walk'. Ellie had previously taken car rides with both her main and occasional caregivers, as well as outdoor walks with her main caregiver.

Example 2 - Ellie stands in front of the speech board, which displays the main menu. She selects the representation for 'say hello to' (a drawing of a waving hand), which opens the corresponding sub-menu. While the caregiver moves away to check on another resident bird, Ellie selects the representation for 'bird friends' (a picture of one of her bird friends), to which the caregiver responds "Yes?". The sub-sub-menu of bird friends comprises three options each corresponding to individual birds (respectively represented by their picture) with whom Ellie had historically been video-calling. She then selects the picture of the parrot named 'Cookie'. The caregiver responds "Do you want to call Cookie? Let me see if he is available".

4.2 Results from Validation Challenges

As mentioned above, to begin to validate the intentionality of Ellie's selections, we presented her with three different kinds of challenges, aiming to test: 1) her persistence in requesting items when these were not offered in response to a selection; 2) her propensity to search for representations corresponding to items of interest whose placement within the interface menus had been randomly changed between sessions; 3) her response to being offered items that did not correspond to what she had selected. Below we report the quantitative results of these tests as well as the qualitative description of a few examples of incorrectly fulfilled requests for food and physical interaction.

4.2.1 Persistence Behavior. For 'persistence' behavior, we observed whether Ellie returned to select a previously unfulfilled selection. For the analyzed time period, the caregiver did not fulfill 148 destination selections. Subsequent to lack of fulfillment, during the same session Ellie selected the same representation again once more (P1) on 38.5% of unfulfilled selections, twice more (P2) on 8% of unfulfilled selections, and 3 or more times more (P3) on 1% of unfulfilled selections. When she made a selection and her request was immediately fulfilled, her corroboration rate was 92%; when her selection was unfulfilled and she selected it again once (P1), her corroboration rate upon fulfilment was 94% (n = 68) (See Figure 4). There were no instances in which, upon an unfulfilled selection, she selected the same option again twice or more (P2, P3) and her selection was eventually fulfilled; so, in those cases corroboration does not apply, because she did not receive the item or activity.

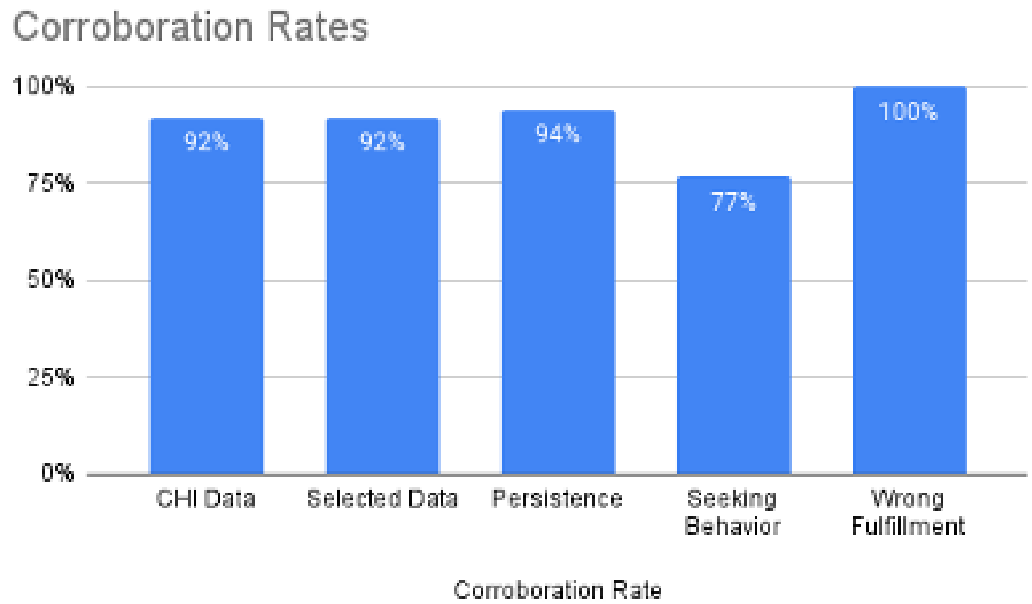

Figure 4: The parrot's corroboration rates. In the first bar, the original (formerly published) data set of 92%; in the second, a consistent 92% from the selected data analyzed for fulfilled selections in the presently-analyzed data; third, the parrot's persistence corroboration rate of 94%; fourth, her corroboration rate dropped to 77% when presented with randomly rearranged representations; and lastly, her corroboration rate of 100% when presented with the requested object following "wrong fulfilment."

For 'menu persistence' behaviour, we analyzed the number of destination representations Ellie selected in fulfilled selections vs. unfulfilled selection circumstances. There were 76 unfulfilled and 51 fulfilled menu selections. When requests were unfulfilled, Ellie averagely made one additional selection in the same menu (P1) 66% of the time, two additional selections in the same menu (P2) 49% of the time, and three or more selections in the same menu (P3) 32% of the time. (Figure 5.) We do not know how strong her desire was for the selections, but the fact that she continued to persist may indicate a stronger desire.

4.2.2 Seeking Behaviour. When searching for her favourite treat, 'sunflower seed', in a 'treat' menu featuring the randomly placed representations of five different treats (two less favored items and 3 favored items), the parrot selected 'sunflower seeds' in 20 out of 30 trials, regardless of the item's placement. Other selections included: 6 times broccoli, 2 times water, 1 time nut, 1 time cheese (Chi-Square for selection distribution: $X2(4) = 43.68$, $p < 0.001$) (see Figure 6). She also corroborated 23 of all her selections (76.6%) when they were randomized: 20 'sunflower seeds' selections (100% corroboration), 1 'nut' selection (100% corroboration), 1 'cheese' selection (100% corroboration), 1 'water' selection (50% corroboration). (Figure 6).

4.2.3 Wrong Fulfillment Behaviour. The parrot was offered a variety of 'wrong' items and experiences, which did not correspond to her selections, across 9 trials. These included wrong tablet games, wrong books, wrong food items of the same value to her (e.g., seed ball instead of sunflower seed, both of which she likes), and food items of different values (e.g. broccoli, which she generally dislikes, instead of sunflower seeds). She rejected 100% of the 'wrong fulfillment' offerings. After each of these she was finally provided with the correct item and corroborated 100% of the originally selected item once received (see Figure 4).

4.2.4 Qualitative Example Descriptions. Example 1 - Ellie stands on her perch with the speech board in front of her. The interface displays her 'treat' menu, which shows 12 thumbnail pictures: 3 are of food items corresponding to familiar treats (i.e. sunflower seed, nut, cheese) and 2 are of food items for which she has previously shown no interest (i.e. water, if she is satiated, and broccoli, a novel option). Ellie selects the representation for 'sunflower seed' (a picture of the seeds), which historically has been her favourite treat. The caregiver says "Ok" and moves away to fetch a corresponding item, except instead of offering Ellie a sunflower seed, she offers her a piece of broccoli. Ellie recoils, then approaches and lightly touches the broccoli with her beak, recoils again and cleans her beak against the edge of the tablet. The caregiver then moves away to approach again asking, "How about a seed-ball?" and offering pieces of the corresponding item, which historically Ellie has shown to like. Ellie tastes and drops the fragments without consuming them. The caregiver says "No? OK" and moves away, approaching again with a few sunflower seeds, which Ellie consumes. As the caregiver moves away again to fetch something else, Ellie exits the 'treat' menu, which lands her on the desktop, from which she selects the 'picture

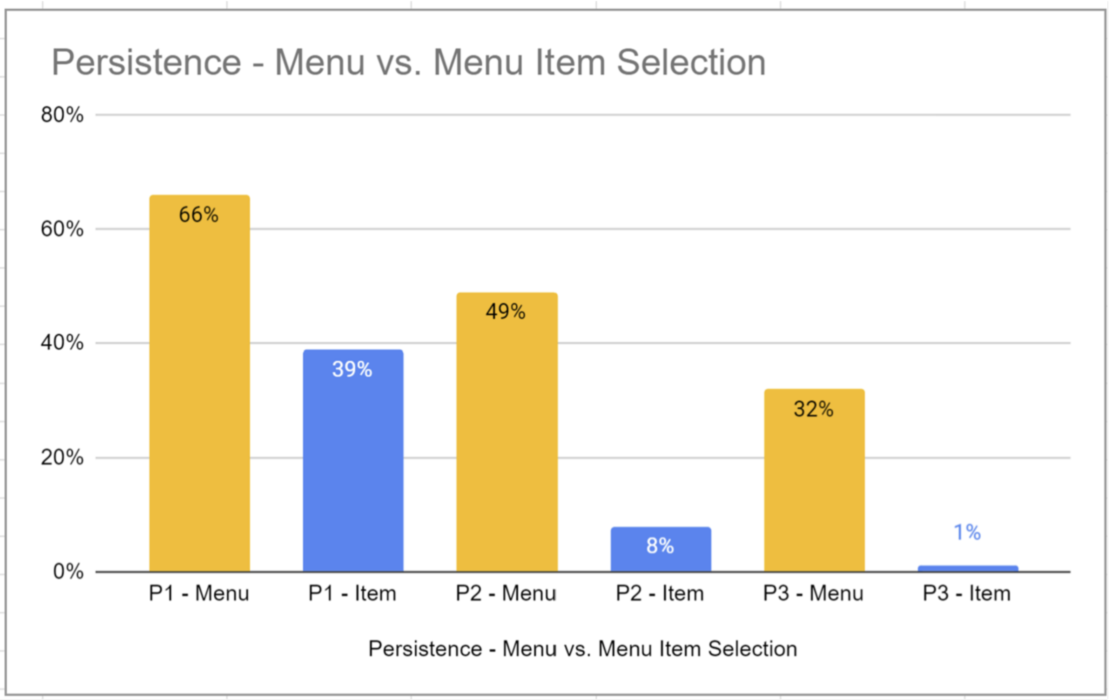

Figure 5: The parrot's persistence rate when comparing menu versus menu item selection during the same session.

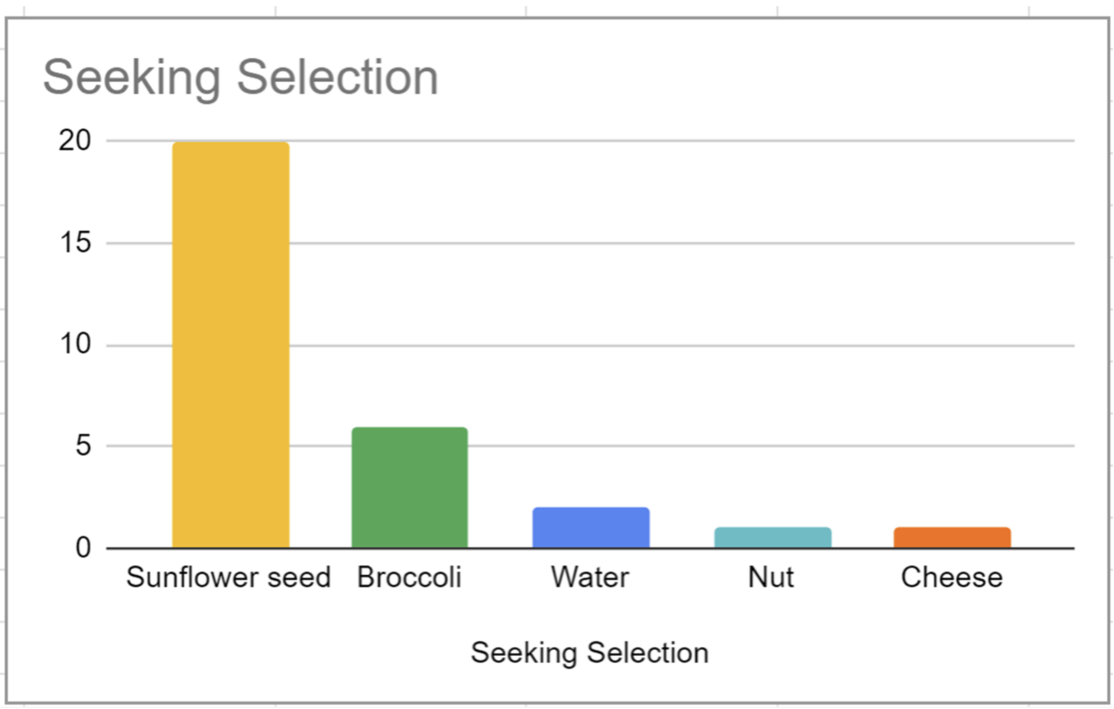

Figure 6: The parrot's selections when they were rearranged randomly across 30 trials. The parrot selected "sunflower seed" 20 out of 30 randomized trials and corroborated 76.6% of selections.

gallery' menu. This contains picture thumbnails of a range of objects with picture albums of different object categories, including food items. Ellie selects a picture album that contains pictures of the treats used for the test and, when this opens, she selects the 'sunflower seed' thumbnail, which expands the sunflower seed picture to full screen. Ellie sits back waiting.

Example 2 - Ellie stands on her perch with the speech board in front of her. The interface displays the same 'treat' menu described above. The caregiver asks Ellie whether she wants any treats and Ellie selects the representation for 'seed-ball' (a picture of a seedball). The caregiver asks "Want a seed-ball?" but instead offers her a piece of apple, a treat that she has historically been shown to like. Ellie takes it in her beak by a corner, tastes it, and drops it. The caregiver asks "Do you want this?", as she offers her another piece of apple, which Ellie takes, tastes and drops. The caregiver now offers her a seed-ball and asks "Do you want this? Seed-ball?". Ellie takes the seed-ball in her beak, then takes hold of it with her foot and starts nibbling on it, consuming almost all of it. Shortly afterwards, the caregiver asks Ellie if she wants anything else. Ellie selects the representation for 'sunflower seed'. The caregiver says "Sunflower seeds?" but offers her a piece of broccoli instead, saying "Some broccoli?". Ellie takes and immediately drops the broccoli. The caregiver then offers her a few sunflower seeds, saying "Here are sunflower seeds". Ellie takes and consumes the seeds. The caregiver then asks "What would you like next?" and Ellie selects the representation for 'seed-ball'. Instead, the caregiver says "Here is apple", as she offers a piece of apple. Ellie takes the piece in her beak and immediately drops it. The caregiver then says "No? Ok, seed-ball" and she offers Ellie a seed-ball, which she grabs with her foot and consumes. While Ellie consumes the seed-ball, the caregiver exits the 'treat' menu, bringing the interface back to the main menu of the speech board. She then asks "Was that yummy?", at which point, Ellie selects the 'food-and-drinks' menu, then the 'to eat' sub-menu (a different sub-menu than the one containing sunflower seeds and seed balls); then Ellie presses the representation for 'apple'. The caregiver asks "Do you want the apple now?" and offers Ellie a piece of apple. While the apple rests on the caregiver's hand, Ellie nibbles on it, then the caregiver rests the piece on a support next to Ellie, where she continues to eat it.

5 DISCUSSION

5.1 How Ellie Used the Speech Board

As our findings suggest, many of Ellie's interactions with the speech board seem to correlate well with Jakobson's functions. This is especially the case for the conative function (63.6% of selections) with goal-oriented behaviors that appear to be corroborated (92%). This is consistent with research that highlights how important it is for animals to exert agency over their environment [83]. Because Ellie lives in a domestic environment over which a human caregiver has primary control, influencing the behaviour of the caregiver, by selecting representations of items or activities she seemingly wants, allows Ellie to exert a measure of control over her living environment through a human proxy, facilitated by the speech board medium. Moreover, the kind of conative interactions that Ellie manifested map onto key biological functions of animal communication, namely: acquiring resources such as food (15.11%) from a parent (in this case a human caregiver); maintaining social relations (30.8%) with flock members (in this case a human cohabitant); and cognitive enrichment (53%), in the form of indoor 'games' and outdoor activities, which in the wild would be afforded by the complexity of parrots' living environment, with its variety and challenges, including the need to maintain territory, navigate, and solve other daily survival problems.

Additionally, Ellie's selections that had correspondence with the emotive function (25.2%) potentially offer some insight into aspects of her experience that she might have strong feelings about. This kind of expression plays an important function in human communication, as underscored by Jakobson's model. But it also fulfills an important biological function in animal communication, as it is instrumental in modulating social interactions and, thus, in maintaining functional social relations (e.g. expressions of disapproval or affiliation, contentment or distress). Similarly, Ellie's selections that corresponded to the phatic function (10.7%), seem to highlight her propensity for establishing interactions with her caregiver, seemingly serving a similar function as in humans, to keep the social interaction going. Both emotive and phatic utterances plausibly play an important biological function in the relationship between Ellie and her caregiver, enabling the former to engage the latter in exchanges that have the potential to nurture their bond and maintain their social roles, since, from the bird's point of view, Ellie's caregiver might be regarded as a part of her 'interspecies flock'.

A very small percentage (.5%) of Ellie's selections seemed to correspond to Jakobson's referential function. While this result certainly calls for further exploration, one possible explanation is that in the animal kingdom referential communication serves the biological function of 'describing' for other members of the same social group where resources might be found (e.g. bees' dance mapping the location of food sources) or where danger might come from (e.g. prairie dogs' referential calls describing the appearance and location of potential predators). This is vital when animals live in the wild, where resources are scarce and dangers are plentiful, and the ability to describe one's surroundings to members of one's group might mean the difference between life and death. In contrast, Ellie's circumstances do not present this kind of pressures; she has shelter and is safe from potential predator, she has access to plenty of food and other resources and is generally comfortable in her environment, so there is no pressure on her to engage her caregiver in referential communication about her surroundings, which might be why she did not. Of course, it could simply be that Ellie was just learning to use the speech board to engage in referential communication or that the speech board did not offer sufficient opportunities to engage in this kind of communication.

When coding Ellie's selections, we did not encounter Jakobson's poetic or metalinguistic functions. This is not surprising, since these functions imply a higher order of language (or medium) use that Ellie is unlikely to have. The speech board and the rudimentary form of communication that it affords is not one with which Ellie evolved. This is not to say that a speech board that featured different options might not support poetic and metalinguistic communication in parrots, the extent of which possibility might be investigated in future.

5.2 Evidence of Functional Communication

The findings from our validation tests provide strong evidence suggesting that Ellie uses the speech board to engage in exchanges with her caregiver intentionally and purposefully. Persistence behaviour data suggests some determination in her pursuit of specific outcomes, as strongly supported by the high corroboration rates (92% for immediate fulfilment, 94% for fulfilment after a repeated selection) once she finally received the selected item or activity. The fact that, albeit marginally, the corroboration rate is even higher upon fulfilment of repeated selections also suggests that Ellie really wanted the outcome corresponding to the selected representation.

Seeking behaviour data suggests that her selections were not determined by their placement on the screen (i.e. by bias that might arise from interface design). Rather, most of the times, she was able to find and select the representation corresponding to her preferred treat, regardless of its random placement in the 'treat' menu. Her

76.6% corroboration rate upon receiving the corresponding item (Figure 6) might suggest that the random displacement of representations from one trial to the next might have had a confounding effect on her selection, but this could possibly be explained with the fact that Ellie had never encountered that particular challenge before. Additionally, parrots, pigeons and other species such as primates have been found to averagely score 67%-80% on discrimination tasks in research settings [16]. Thus, a selection accuracy rate of 76.6% for preferred treat selection between 5 randomly moving icons would be considered within a standard range of accuracy on a discrimination task.

Finally, although a small sample size, wrong fulfilment data provides compelling evidence of Ellie's intentional and purposeful communication via the speech board's icons. She decidedly rejected outcomes that did not correspond to her icon selections, while corroborating 100% of the items corresponding to the selected icons once her selection was correctly fulfilled. Qualitative observations provide further support of her intentional engagement. For example, she recoiled from unwanted items (e.g. broccoli), taking hold of them with her beak only to immediately toss them aside. In contrast, once they were finally offered, she grabbed wanted items (e.g. seed ball), holding them securely with her foot while she consumed them. Ellie seems to know not only what she wants, but also when she wants it. For example, she rejected a piece of apple when it was offered to her in substitution for the sunflower seeds she had selected. However, directly after eating the sunflower seed, she entered a different menu, found the icon for apple, selected it and, when a piece of apple was offered to her, she consumed it. Moreover, Ellie seems to be well versed in recognising the icons for her favourite items (i.e. sunflower seeds) in their different formats and remembers where to find them in her speech board. For example, after selecting the icon for sunflower seeds in the treat menu, consequently receiving several incorrect offerings ,and then finally being offered it, she exited the speech board interface to go to the tablet's home screen, located and opened a photo gallery app, searched for and opened an album containing the photos of treats, located the sunflower seed thumbnail, and then opened the full sunflower seed picture which then spanned the screen, leaving it there for her caregiver to find.

Overall, our findings suggest that Ellie uses the speech board and the functional communication system it affords to intentionally and purposefully engage in 'linguistically' and biologically functional exchanges with her caregiver. This supports the idea that speech boards provide a useful mean for parrots to communicate with those who care for them to express their agency and exert a measure of control over their environment via human proxy, but also to nurture and maintain social relations within their 'interspecies flock'. Because of this, speech boards could also constitute a useful mean for researchers to investigate parrots' cognitive and communication abilities. This raises the question as to how the functional communication systems afforded by speech boards should be designed to best support parrot communication.

5.3 Design Implications

While previous research has highlighted the importance of designing screen-based enrichment applications for parrots that provide highly sensitive touch-screen capability and large interactive interface elements to avoid selection errors [36], our findings highlight other specific implications:

5.3.1 Supporting Communication with Menus and Menu Options. Based on Ellie's use of representations as analyzed through the lens of Jakobson's Model of Functions of Communication, we would recommend prioritizing menus and corresponding menu options that could support conative communication exchanges to help parrots express their agency and exert a measure of control over their environment via human proxy. These would include primarily menus and menu options supporting the selection of, and request for, resources such as food and drinks, or special treats; as well as menus including representations for enriching activities that are cognitively challenging and that might involve the use of toys, learning enrichment, other stimulating objects, or a change of environment.

Although experiences are subjective, we suggest that providing menus, corresponding menu options, and training that facilitates emotive and phatic communication could help the birds nurture their bond and maintain their social relation with caregivers. These could include representations that, along with body language, emphasise the expression of possible states (e.g, simple emotions, perception of ambient or bodily temperature) to support emotive communication; as well as representations facilitating colloquialisms (e.g. weather conditions) to support phatic communication.

This is not to say that other communication functions should not be supported, but rather that these seem to warrant priority, also in consideration of the fact that the space on the screen of a speech board is limited. In this regard, designers and caregivers could consider using representations to refer to combinations of objects (e.g. seed ball) and specific actions (e.g. 'want to eat', rather than 'want' and 'eat'), to maximise expressivity and minimise the need to make multiple selections to produce meaningful 'utterances'.

5.3.2 Evaluating Intentionality and Communication. If speech boards are to be used to study parrots' communication abilities, we suggest that the devices should themselves afford the birds a greater degree of control, enabling them to initiate and end interaction sessions. For example, they might turn on the device simply by tapping on the screen, whose desktop could feature a large touch sensitive widget, which the birds could touch to open a speech board. A large exit icon could then be available within the speech board application for them to easily close the session.

Just as, we suggest, enabling the parrots to engage in speech board interactions more autonomously would be important to study their communication abilities, equally important would be for these devices to be able to track and log the birds' interactions to gather evidence of intentionality and communication based on recorded action sequences (e.g. menu and option selections) and their timings. Embedded or external cameras might be able to capture information such as body language and other behaviours that might corroborate interactions. It might also be useful to randomize the distribution of menus and menu options on the interface for some tests. Of course, for ethical reasons, it would be important to ensure that any systems settings did not accidentally cause frustration avoidance, for example by allowing the birds to choose the extent to which they are willing to be challenged for what reward. This would be necessary to ensure the speech board use did not become an aversive experience.

5.3.3 Limitations. Despite the promising findings of functional communication in Ellie's speech board data and tests, this study included only one cockatoo. While detailed observations of her selections and related behaviour yielded compelling insights, conditions do not allow the generalization of the findings. Different parrots may respond differently and display alternative representation selections. Future studies involving more parrots, and even across species, could provide greater insights and allow findings to be generalized.

Ellie's environmental conditions may differ significantly from those of other parrots. Although based in a family setting, the experiments were conducted in a relatively controlled environment, in which the caregiver took care to blind herself to Ellie's speech board interactions during experimental sessions. These conditions may not reflect the variability in other research settings. Future research should consider parrots in a variety of settings to explore the impact of environment on speech board selections and communicative priorities.

Ellie's selections may be influenced by technological limitations. Ellie only has access to the speech board menus and destination options that have been created for her. Although she had over 200 representations on her speech board during the study, it is possible that an array of other menu and destination options may yield other communicative function results. The data set used in this study was collected over a limited period of time. Longer studies may evidence function priorities or interaction patterns that change over time.

Lastly, of course, although the data was labelled by two different researchers independently, with an IRR of 95%, there is of course room for interpretation in our labeling of all the interactions as belonging primarily to one function or another, the same way there would be in humans, as even Jakobson acknowledged. While the functions we identified seem to be consistent with biological communication functions in animals and with Ellie's circumstances, future studies could further explore these connections.

6 CONCLUSION

This study delved into one parrot's extensive use of an AAC speech board over time. Here, we examined how Ellie's interactions corresponded to some of Jakobson's functions of communication (conative, emotive, phatic, and referential) and may align with important biological functions of animal communication. Quantitative analysis and qualitative descriptions provide interesting insights into Ellie's ability to navigate the interface and to adapt to changes within it. Ellie demonstrated persistence when her selections were unfulfilled by the caregiver, almost invariably corroborating her requests; most of the time, she found and selected her preferred treats when the locations of their representations had been randomly displaced; and she rejected treats whose corresponding representations she did not select, while consuming the treats whose representations she did select. All these are strong indicators of intentional, functional communication. Implications include designing speech board systems that are able to support possible parrot communication and allow for effective study of parrot cognition.

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