Challenges Related to Nonhuman Animal-Computer Interaction: Usability and 'Liking'

Sarah E. Ritvo
Department of Psychology
York University
4700 Keele Street
Toronto, ON M3J 1P3
sritvo@yorku.ca

Robert S. Allison
Department of Electrical Engineering and Computer Science
York University
4700 Keele Street
Toronto, ON M3J 1P3
Allison@cse.yorku.ca

ABSTRACT
Despite a marked increase in the number of hardware and software systems being adapted and designed specifically for nonhuman animals, to-date, nearly all computer interaction design and assessment has been anthropocentric. Ironically, because nonhuman animals cannot provide, refuse, or withdraw consent to participate with ACI systems, valid and reliable evaluation of usability and user satisfaction is crucial. The current paper explores a) the potential benefits and costs of engaging in animal-computer interaction for nonhuman animal users, b) potential animal-computer interaction evaluation concerns, and c) the assessment of 'liking' and 'preference' in non-communicative subjects.

Author Keywords
ACI; AHCI; usability; user satisfaction; nonhuman animal; ethics; animal-computer interaction; human-animal computer interaction

ACM Classification Keywords
H.5.2 User Interfaces: *User-centered design, Evaluation*.

INTRODUCTION

Hardware and software systems are increasingly being adapted and designed explicitly for nonhuman animals (NHAs) such as livestock, domestic pets, and captive exotic animals [3,14,23]. Of late, computer-interaction systems are also being employed to study and assess NHA cognition (i.e., comparative cognition) [19,35].

Despite heightened interest in NHA applications however, to-date nearly all computer system design and assessment has been anthropocentric (designed for humans, by humans). Even the relatively modern concept of *inclusive design*, (i.e., the development of computer systems that "are usable by people with the widest possible range of abilities, operating within the widest possible range of situations" [24 pg 3] has presupposed human 'people' as users. Not surprisingly then, current measures of usability and user satisfaction suffer from anthropocentrism as well - relying on standards, methodologies and measures designed for humans. Given NHAs' inability to communicate via speech or writing, many of these methods are not applicable to the design and testing of animal-computer interaction (ACI) interfaces.

Ironically, because NHAs cannot provide, refuse, or withdraw consent to participate with ACI systems and in ACI research, a comprehensive and valid evaluation of affect, usability, user experience and user satisfaction is particularly important in ACI. Engaging with a computer system involves investment on the part of the user. That is, in order for an ACI interaction to be successful, the intended NHA user must independently and spontaneously *choose* to invest time, cognitive effort and physical energy in the system [12]. This is particularly true when the user does not have prior experience with the current system or similar systems. Because the rational benefits and costs of the ACI system cannot be orally conveyed to an NHA user and s/he may not appreciate said benefits in any case, it is important that usability and user experience be thoroughly assessed. In other words, if a user cannot formally *volunteer* to engage with ACI systems or is cognitively incapable of comprehending (a) his or her individual rights and autonomy or (b) the potential benefits and costs entailed, then it is essential to ensure that the NHA user *is not* suffering and *is* benefitting from any ACI system s/he is exposed to. At the very least, the derived benefits of ACI engagement should demonstrably outweigh the implied costs.

COST-BENEFIT ANALYSIS

Accordingly, evaluating ACI systems requires careful consideration of the benefits and potential costs for NHA users [21].

On the one hand, ACI can provide empirically supported benefits to both animal users and, in the case of animal-human-computer interaction (AHCI) systems, human users alike [18,26]. ACI and AHCI systems can improve NHA welfare and physical well being, remotely providing exercise, recreation, entertainment, distraction and comfort.

Take for example a human-canine computer mediated communication system that allows a human user to remotely interact with a canine user during periods of extended separation (e.g., work days, vacations, business travel, etc.). Rather than sleeping his day away or engaging in destructive anxiety- or boredom-induced behaviours, a dog can look forward to the physical, emotional and cognitive benefits of periodic play sessions with his caretaker. Similarly, an interactive environmental enrichment system could provide entertainment, exercise, cognitive challenges and gratification in an ecologically appropriate manner for captive exotic animals.

AHCI systems that facilitate human-nonhuman animal communication and play also have the potential to bring species closer together. Bekoff and Pierce [6] suggest that play is a unique category of behaviour that tolerates asymmetries more than other categories of behaviour. In other words, human-NHA computer-mediated play provides an unparalleled opportunity for understanding, exploration, empathy, alliance, meta-communication and the equalizing of power relations.

Consider for example, the unequal power relations inherent in zoo settings in which animals are *placed* on *display* for humans' education and *entertainment.* To address this concern Ken Schweller designed RoboBonobo [1], a robotic ape armed with a water gun. Captive bonobos at the Bonobo Hope Great Ape Sanctuary in Des Moines control the robot to chase and squirt human visitors. Although inclusion of weaponry in AHCI has been criticized, systems for captive animals like this one can provide interactive recreation for human users and NHA users alike. More importantly, RoboBonobo also affords the opportunity for NHA users to *choose* the type, quality and duration of interaction with human visitors thus providing NHAs a degree of control and power over their environment that they would not normally possess. Human-animal intimacy fostered by these types of ACI systems also has the potential to increase popular concern for the user-species and their natural habitat, thereby promoting pro-animal and pro-ecological conservation and activism. On a more practical level, ACI systems can also provide a means for human caregivers to remotely train and monitor the health, safety, and activity of NHAs in their care [21].

As well as empowering and enriching the lives of the NHA, humans can derive similar benefits from AHCI. Savage et al.'s [29] service dog wearable computer demonstrates the potential for ACI systems to enhance animals' capabilities and applicability which in turn, also enhances the independence, inconspicuousness, and safety of the humans they service. The UNAM-CAN [29] helps service dogs perform complex tasks by breaking those tasks down into simple, sequential, intelligible and practicable behavioural commands delivered via loudspeaker. This allows the canine user to perform tasks that s/he couldn't perform independently (e.g., rescue, surveillance, guidance, menial tasks, etc.) [29]. Imagine the potential of service animal wearables that also monitor the health status of the humans they assist.

Despite promised benefits, ACI systems also have the potential to harm NHA users. In humans, access to computers has been linked to risk of decreased physical activity, obesity, anxiety, depression, aggressiveness, seizures, repetitive use injuries, behavioural and social problems [2,8,11,22,31,37,39,40].

Anthropomorphic and anthropocentric design of ACIs poses unique risks as well. Take for example, the Sensor Cow [5] that allows human and NHA users to dance with one another to improvised music. Although obviously entertaining to the human user, the entertainment or other value to the cow user is questionable at best.

Beyond providing only questionable benefit for NHAs, ACI can also entail tangible costs for the user. For example, suppose a collar, anklet, ear tag or other wearable is necessary for a zoo NHA to engage with an ACI system. Consequently, the wearable device is either chronically attached or fitted to the NHA by caretakers on a regular basis. Not only may this wearable be physically uncomfortable or restrict movement, but it may also affect species-specific natural behaviour and interaction with conspecifics (e.g., social grooming, dominance hierarchies, husbandry behaviours, etc.)

In cases such as these, it is important to ensure that the calculated benefits of interaction with the computer system outweigh potential costs. For example, in the case of ACI wearables, if the estimated costs outweighed the benefits, the wearable could be re-designed to be lighter, more discreet, or more ecologically inconspicuous to the degree neccessary to tip the cost-benefit scale in favour of benefit.

GUIDELINES & METHODOLOGIES: BREAKING NEW GROUND

Many of the established guidelines and methodologies developed to assess this cost-benefit balance for human-computer interaction (HCI) systems are simply not applicable to illiterate, nonverbal NHAs. As has been the case in the design of HCI systems for the disabled, in the absence of guidelines, a designer or user experience assessor "may end up drawing from inappropriate design advice" from "best available practice" [24 pg 4] without questioning the validity of doing so in a novel situation (e.g., with NHAs) or with a new technology (e.g., ACI systems). Consequently, although guidelines are by their nature generalizations and simplifications and can thereby impede innovation, development of a standardized set of guidelines and methodologies for consideration and guidance of the design, analysis, and evaluation of ACI systems is crucial as a means of safeguarding ACI evaluation from designers' and evaluators' potential anthropomorphic bias.

Evaluation Concerns

Te'eni et al. [34], identify four central concerns that should be considered in the evaluations of HCI systems. We argue that as a point of departure in the development of ACI-specific evaluation guidelines and methodologies, these concerns can also be considered in the evaluation of ACI systems.

(1) The first concerns the user's physical level, focusing attention on the physical fit of a system. Inevitably this involves consideration of the user species' physical capacities and incapacities. In the case of nonhuman primates (NHPs) for example, although they possess hands that look similar to humans, they rarely use their fingertips to explore and manipulate objects, preferring to user their knuckles instead. This tendency could make touchscreen interfaces difficult or uncomfortable to use without some type of stylus. However, nonhuman primates' superhuman strength, and propensity to break objects into smaller pieces makes the design of a stylus that is NHP-resilient a challenge. Evaluation of a computer system at the physical level therefore, should ensure that the system accommodates the user's physical tendencies, strengths and weaknesses and does not directly or indirectly cause injury, discomfort or illness.

(2) Users must understand a computer system in order to use it. Accordingly, the second type of computer interaction evaluation concern relates to the user's cognitive abilities and limitations. These include the user's perception, memory, reasoning, judgment, mental models, learning, etc. Specifically, in order for a NHA to understand an ACI system, the system must lend itself to the species-specific cognitive tendencies, strengths and weaknesses of the intended user(s). If this is achieved, the system will be intuitive, easy to learn and use, memorable and will result in few errors as well as consistent and effortless *recovery* from those errors.

(3) The third type of evaluation concern relates to users' affective needs. This is of particular importance in ACI systems, as many categorically seek, as their main design purpose, to enrich the lives of NHA users. If users do not engage with and/or do not enjoy an ACI system, this goal will not be achieved. A system that is affectively suitable for the target species will be appealing, engrossing, aesthetically pleasing, trustworthy, satisfying, enjoyable, entertaining and fun.

(4) The final type of computer interaction evaluation concern identified by Te'eni et al. [34], relates to utility. In other words, how useful or extrinsically motivating and rewarding is the computer system to the user species? If a user believes that the computer system's functions increase their capability, are useful in achieving their needs or goals, or allow them to do things they would not be capable of without the system, they will be more likely to adopt and use it. For example, Ken Schweller's RoboBonobo [1] allows Bonobo-users to interact with human visitors in a manner that is appealing to the Bonobos and in a way that is not possible without the AHCI system.

In developing guidelines to address these concerns we are confronted by the fact that guidelines are, by their nature, simplified and general rules applicable to a range of users and systems. As Nicolle and Abascal [24 pg 4] explain in relation to HCI design for impaired users, guidelines "are usually drawn from best available practice, sometimes applied to different situations and technologies and often not validated for your own specific area. Where guidelines are more precise… they are difficult to apply to other technical areas or are considered too restrictive… Frequently, it is also true that design recommendations are conflicting, not only between different sets but also within the same set of guidelines". Given the enormous diversity of NHA species (physically, cognitively, perceptively, emotionally, etc.) developing a set of guidelines that apply to ACI universally is difficult, if not impossible. Instead, what may be required is a set of general principles for ACI designs that addresses common ACI evaluation concerns, coupled with more precise and differentiated guidelines that address species-specific concerns. The development and application of these latter guidelines and related methods will depend on extensive and thorough species-specific research and user trials.

NONHUMAN ANIMALS AND 'LIKING'

The evaluation of usability and user satisfaction in ACI systems raises questions regarding (a) what NHAs *like,* (b) how *liking* can be measured in a nonverbal (and for the most part, non communicative) participant and (c) whether such concepts as *liking* are even appropriate for some species. Take for example Tan et al.'s [9,33] *Metazoa Ludens*. In this online mixed reality computer game a human user remotely controls the movement of species-specific bait (represented virtually by a human avatar) that the hamster user pursues. Through this system the hamster and human play a virtual game of chase. Or consider a video game developed by researchers at Princeton University for bluegill fish in which fish users 'hunt' moving dots projected into their tank. Although ostensibly exciting, interesting and enjoyable for human and animal users alike, these types of AHCI systems invoke fundamental and important questions regarding NHA users and the intention, purpose, and future of ACI:

- Does the target species *like* to *play*?
- Does the target species *like* to play *games*?
- Does the target species *like* to play games *with humans*?

- Would a NHA withdraw from a game if they did not enjoy it?
- Would a NHA necessarily continue to play a game if they enjoy it?
- What does 'enjoyment' and 'liking' look like in the target species?
- How can 'enjoyment' and 'liking' be objectively measured in a nonverbal user?

Unlike in HCI, in ACI, commonly used methodologies for analysis of usability and user satisfaction are (a) not established (e.g., guideline review), (b) not appropriate (e.g., a human cognitive or pluralistic walk- through of designs for NHA users), or (c) not feasible (e.g., surveys, questionnaires, self-reports, interviews, Technology Acceptance Model measures, etc.) [21,34]. Even in lab experiments and field studies—perhaps the most appropriate measure of NHA usability and user experience—measurements of 'liking' are complicated by NHAs' inability to vocalize and perhaps even conceptualize 'liking' and 'disliking'.

Furthermore, it can be difficult to infer affective states from external behavior. For example in highly-publicized experiments in the 1950's researchers discovered that rats with electrodes implanted in specific brain regions would repeatedly press a lever to self-stimulate these sites [25]. These regions were initially interpreted as reward or 'pleasure' centres, as the animals would endure electric shock on the feet or forgo eating when hungry to receive stimulation. However, subsequent research suggests the situation was more complex. Others have interpreted these experiments as evidence of intense 'wanting' rather than 'liking', noting that irrationally intense wanting can, in fact, be negative (e.g., addictive behaviour) [7].

ASSESSING PREFERENCE IN NHAS

Given most NHAs' inability to directly communicate internal subjective sentiments through speech or gesture, the study of NHA 'liking' is challenging both from a methodological and a theoretical standpoint. Do NHAs "like" or "dislike" as humans do? How can enjoyment be recognized in species so different from our own? Accordingly, those assessment methods that do not rely on subjective human interpretation of NHAs' internal thoughts tend to rely on various measures of 'preference' rather than 'liking'. That is, choosing an item or condition over another, presumably based on either (a) *liking* (i.e., enjoying) one thing/condition more than another, or (b) *disliking* one thing/condition less than another. At the very least, preference assessment indicates to the assessor if an NHA prefers to do Activity A, Activity B, or neither, or engage with System A, System B, or neither. An important question concerns how preferences can be assessed, if they cannot be directly communicated. Answers to this question can be found by looking to established methodologies used in the field of Psychology for assessing non-communicative human infants' and NHAs' preferences. Review of the Psychology preference literature indicates three main approaches:

(1) Behavioural observation during stimulus exposure

Looking paradigms (e.g., looking direction, looking time, fixation duration, frequency of look-switching between simultaneously visible objects, etc.) have been the dominant method to study infant visual, olfactory and auditory preferences since the 1960's [4,10,13,30,36,38].. However, the use of behaviour as a preference measure most often requires some, (albeit operationally defined), subjective interpretation and/or classification of the test subject's behaviour. In the case of NHAs, this risks inclusion of biased anthropomorphic interpretations of NHA behaviour in the experimental paradigm. Furthermore, the presumed link between looking behaviour and cognitive processing itself has been questioned [4]. Aslin describes looking paradigms as a "many-to-one mapping problem: many potential 'hidden' variables contribute to a single dependent measure" [4 pg. 48]. The use of looking paradigms in the study of NHA preference is further complicated by the difficulties or limitations of positioning and restraining subjects in physical positions that allow the required type of eye observations (particularly in zoos and aquariums).

The use of approach/avoidance as an indicator of preference in NHA research appears to avoid these difficulties. In this paradigm, preference is measured by the number, frequency and/or extent of approaches (movement of the body towards the stimulus) vs. non-occurrences (absence of response within a predetermined amount of time). However, given the tendency for many species to approach any stimulus (regardless of whether or not the stimulus is reinforcing), the utility and accuracy of this paradigm is also limited.

(2) The least-aversive or most-desired choice paradigm

The second approach, used to assess non-communicative subject preference, involves a least-aversive choice paradigm in which the test subject is forced to choose between stimuli. For example, in NHP auditory preference studies by McDermott and Hauser [20], tests were conducted using a V-shaped maze, with each branch of the maze paired with a distinct auditory stimulus. Subjects were placed at the entrance to the maze, thereby forcing them to enter one of the two available branches. The subject's chosen branch was interpreted as a 'preference' for the accompanying auditory stimulus. However, in this paradigm it is impossible to know if the subject is being forced to make a 'least aversive choice' or is expressing a most desired choice [16]. Consequently, preference in this paradigm can be interpreted as the *least disliked* of two stimuli *or* the *most desired*. Furthermore, this paradigm does not allow measurement of subjects' spontaneous motivation to listen to either of the stimuli.

(3) Participant-controlled procedures

Participant-controlled procedures appear to be the most appropriate and accurate approach to studying preference based on "liking" in non-communicative subjects. Lamont [16] argues that this approach allows greater confidence in inferring that subjects 'like' one stimulus *more than* another, as opposed to concluding that they 'dislike' one stimulus *less than* the other. A participant-controlled procedure allows subjects to *choose* the duration, and in some cases, the type of stimulus during testing. For example, in a visual preference study using a sensory reinforcement procedure by Tanaka [32], chimpanzees touched a button to view a stimulus. Images were continuously presented while the subject pressed a button, and if the button was touched within 10s of the previous release, the same image was presented again. In this paradigm, the image itself was an intrinsic reward and visual preferences were assessed by the frequency and duration of specific image viewing.

In the first author's investigation of NHA music preference using a participant-controlled dichotomous-choice design, orangutans at the Toronto Zoo were trained to indicate preference via touchscreen choices [27]. Following exposure to a sample of one of seven music genres, subjects touched one side of the screen to replay the previous music sample, *or* they touched the other side of the screen to listen to the equivalent amount of silence instead (Fig. 1). Contrary to expectation, results indicated that they (a) preferred silence to music (or were indifferent) and (b) did not favor one music genre over another. As a point of comparison, had a least-aversive choice paradigm (i.e., assessment method 2 above) been employed to assess music preference in this study, inferences would be limited to concluding that the subjects found silence less aversive than music, or were indifferent and that they did not find any of the musical genres less aversive than others. Although subtle, these conclusions are fundamentally different and

Figure 1. Budi, a Sumatran orangutan at the Toronto Zoo makes auditory preference choices on a touchscreen

less precise than those allowed/provided by a participant-controlled assessment method.

Another common participant-controlled procedure is a free-choice task with single-paired or multiple-stimulus methods. In this paradigm subjects choose between concurrently presented pairs of stimuli [15]. Preference is defined as selecting one stimulus more frequently than the other. When subjects have chosen between every combination of stimuli, the stimuli are ranked based on selection percentages. Food reward may be delivered to motivate subjects to participate but the reward is delivered irrespective of stimulus choice. This approach differs from a "least aversive" choice paradigm in that subjects are not forcibly subjected to the stimuli (as is the case of the V-shaped maze), but rather can choose to terminate participation, thereby limiting exposure to stimuli at any time.

ACI Preference Assessment in Practice

ACI designers have started to adapt these assessment methods for ACI usability and user experience tests. For example, Lee et al. [18] attempted to evaluate user satisfaction with a wearable computer jacket via the least-aversive or most-desired choice paradigm. A chicken user, over a period of four weeks, was given the choice to spend time in one of two available cages. In one cage s/he was consistently dressed in the wearable and in the other s/he was not. To assess *degree* of preference and motivation the researchers weighted the push doors at the entrance to the wearable cage, thus requiring more effort on the part of the chicken to enter the ACI cage than the neutral cage. The chicken's choice of the wearable cage despite disincentives led researchers to conclude that the wearable was experienced as "pleasurable" [18]. Similarly, Cheok et al. [9] employed a participant-controlled preference study to assess hamster user satisfaction by enabling the user to initiate and terminate participation in the ACI system.

Although these NHA usability and user satisfaction assessment methods are both laudable and promising, more research is required to assess their *validity* and reliability as well as to investigate alternative means of NHA user experience assessment.

Caveat: Alternative Explanations

Even the preference assessment methods currently favoured for non-communicative subjects should be approached with restraint and consideration in relation to NHAs. Behavioural patterns that appear to indicate NHA 'preference' or 'liking' can also be motivated by fear, anxiety, natural instinct, compulsions, stereotypies, and/or reinforcement from another confounding variable that the animal has come to associate with the behaviour, object or activity in question. For example, in captive animal facilities stereotypies are not uncommon [17]. Because stereotypies involve persistent, repetitive behaviour patterns, they can be misinterpreted as preference according to (a) the 'approach-avoidance' assessment method (i.e., as several, consistent, decisive "approaches") or (b) the 'participant controlled procedure' assessment method (i.e., as several, consistent, decisive "engagements"). In reality however, stereotypies more likely indicate insufficient mental stimulation and psychological instability. Or, more familiarly, consider a domesticated dog that continues to chase a ball long after s/he has grown too tired and dehydrated to do so without risking his or her health. Is this dog still enjoying the game of fetch? Or are his or her instincts to retrieve so strong, that they trump weaker drives (i.e., 'liking' or 'disliking').

This example raises an interesting question regarding NHA instincts and 'liking' or 'enjoyment'. It could be argued that because it is innate (i.e., not based on prior experience), a strong NHA instinct is by its nature neither enjoyable nor aversive. Rather, it is a complex and specific unconscious response to environmental stimuli, shaped by natural selection [28]. For example, picture the newly hatched sea turtle that without provocation moves from its nest towards the ocean. Does this hatchling 'enjoy' walking across the beach or 'like' the ocean? On the other hand, it could also be argued that that through selection, for the most part, instinctual behaviours are by their nature experienced as 'enjoyable' or 'rewarding' to some degree. If we return to the example of a dog playing fetch, it's hard to interpret the enthusiasm, persistence and wagging tails exhibited during fetch as anything other than enjoyment. One could even argue that humans enjoy socializing because we are instinctually predisposed to form cohesive groups.

CONCLUSION

ACI has the potential to greatly improve the well-being and quality of life of NHAs and to enhance human-animal relations. However, because NHAs cannot provide, refuse or withdraw consent to participate with ACI systems, species-specific usability and user experience assessment paradigms are crucial. In order to achieve validity and reliability, the development of such evaluation methodologies and guidelines requires careful consideration of (a) the potential benefits and costs of ACI systems, (b) the computer interaction evaluation concerns identified by Te'eni et al. [34] (c) the identified strengths and weaknesses of established preference assessment methods used in the study of noncommunicative populations and (d) the influence and power of potentially influential and confounding NHA drives.

Although application of Psychology methodologies for assessing non-communicative subject preference to ACI user experience tests are a good point of departure, and will likely offer useful insights, ACI-specific research is required to assess the *validity* and *reliability* of these appropriated methodologies. Furthermore, given the diversity of NHA species, investigation of alternative species-specific means of NHA user experience assessment is essential, particularly with respect to the confounding influence of species-specific natural instincts.

Although the utility and merit of the pursuit of valid and reliable NHA usability and user experience paradigms is immediately obvious in the realm of ACI, less obvious, but equally important is the potential relevance to HCI as well. Theories, guidelines and methodologies developed for the assessment of individuals with different cognitive abilities and physiology than humans may be directly applicable to exceptional human user populations (e.g., the cognitively and/or physical impaired, the elderly, infants, etc.). Thus, the concerns, considerations and innovation necessary to develop ACI evaluation guidelines and techniques may also inform and benefit future HCI evaluation and human users as well.

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