Waddle: Developing Empathy for Adélie Penguins By Direct Embodiment in Virtual Reality

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Abstract. Empathy is important for fostering social engagement with ecology. In this study we describe *Waddle*, a virtual reality (VR) experience designed to facilitate the direct embodiment of an Adélie Penguin moving through the key stages of their life cycle as an intervention to increase empathy. By collecting pre and post questionnaire data from forty-three grade 3 through 8 students attending a science festival, we find that *Waddle* was successful in facilitating an embodied experience and supported a significant increase in the participants' empathy toward penguins. We also find that greater embodiment was correlated with increased empathy, suggesting a casual relation that invites additional research into designing embodied experiences using immersive technologies as a method for developing empathy and fostering greater social engagement.

Keywords: Virtual Reality · Educational Games · Empathy · Embodiment

1 Introduction

Recent research into embodied learning demonstrates significant promise for teaching complex STEM topics [7], as well as increasing empathy and perspective-taking [3]. Empathy has been proven to lead to increased conservation efforts, such as financial donations to ecological organizations [8, 11], an objective with merits beyond simple content knowledge. Previous work has also explored the use of virtual reality (VR) for facilitating embodied learning experiences with animals, but have often failed to do so [8]. In this study we leverage this previous work, and the notions of gesture congruence [1] and visuomotor synchrony [8], to design a virtual reality (VR) experience in which the learner takes on the body of an Adélie penguin living on Ross Island in Antarctica. We then use this experience to empirically explore how embodiment and empathy are facilitated and related, following three research questions:

RQ1. Does the experience effectively produce an embodied experience of an Adélie penguin?

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RQ2. Does the experience produce measurable increases in empathy for Adélie penguins?
RQ3. Does an increased sense of embodiment correlate with an increase in empathy?

Practically, this work contributes an understanding of how to design educational VR experiences that lead to embodiment and increased empathy for animals. Theoretically, this project contributes an empirical exploration of the relationship between learner embodiment and empathy.

2 Previous Work

To move beyond the goal of increasing descriptive knowledge about ecological systems and into environmentalist action, researchers have explored the promise of educational interventions that facilitate empathy and perspective taking [13]. Pimentel & Kalyanaraman [8] found that developing empathy for an endangered species can reverse "compassion fade" and lead to increases in charitable giving. A similar finding by Swim & Bloodhart [11] demonstrates that empathy and perspective taking are more effective than objective perspectives for increasing environmental action, contrary to popular warnings that prioritize psychological distance.

As a medium that manipulates users' perception and gesture, numerous researchers have explored the various ways VR technology can be used to facilitate embodied learning experiences [4], including what Melcer & Isbister refer to as "direct embodiment" where the actions of the participant are directly mapped to the actions and perceptions of the embodied avatar [6]. An important design principle is gesture congruence, which measures the degree to which movements performed by the learner directly relate to the concept being learned [1]. For example, if a student is learning about movement of an object under a force, the VR design should have them gesture in a similar direction to the force, not in a random direction.

Connecting empathy and embodiment using VR, researchers have explored the use of mixed reality to embody animals. Sierra Rativa et al. [10] developed a Virtual Reality simulation where users embodied a visually and haptically realistic beaver avatar. Their study showed a significant effect of the visual design of the avatar on users' sense of immersion, but not on adopting a 1st-person sense of animal embodiment or increasing empathy. One challenge for adopting a truly embodied experience from an animal's perspective is the control of an avatar of certain animals, which have different postures, skeletal arrangements, and shapes compared to human bodies [5]. Pimentel & Kalyanaraman [8] describe this alignment as visuomotor synchrony. Sierra Rativa et al. [10] discuss a lack of synchrony in their design and propose future design should explore the use of the players' hands to control animal's front paws to increase embodiment.

3 Methods

3.1 Intervention

The VR experience, entitled *Waddle*, is a 20-min Virtual Reality experience that demonstrates visuomotor congruence with an Adélie penguin. Hand tracking mode was utilized, which uses outward facing 3d sensors to identify and track the users hand positions without using additional hand controllers. The experience was developed in consultation with a team of educational game designers, VR researchers, and Jean Pennycook, an Antarctic penguin researcher. Since 2004, Pennycook has spent the Antarctic summers (Oct – Jan) living in a tent near the Adélie penguin breeding colony at Cape Royds on Ross Island near the McMurdo Research Station. Her research team monitors the population of these iconic birds as they respond to changes in their environment. Following several initial meetings with Pennycook, learning about the key life events and activities of the penguins, a design document was developed to explore a potential intervention. This document was reviewed with Pennycook for accuracy and feedback about how it reflected her values, then the project moved into production with minor revisions. During production, minor prototypes were tested internally with public audiences to identify usability issues, then with later iterations again to verify their solutions.

Fig. 1. The landscape of Waddle, with orientation activities on the near side and life activities on far side of the bridge

The experience begins with a series of interactions that are designed to orientate the user to the system. Upon putting on the headset, the user sees a snowy scene with a soft mound of snow surrounding all but one direction forward. Their perspective is approximately 0.5 m above the snowy floor, and they see a beak extending forward where their nose should be. Looking down, they see their white belly and flippers instead of arms. To one side is an icy stone obstacle that acts as a mirror, showing a reflection of the Adélie penguin avatar they inhabit and control. The movements they make are reflected in the mirror. To another side is a signpost with a graphic of a penguin standing on one foot with a rounded, double-sided arrow above its head. This sign attempts to communicate that penguins move by waddling back and forth from left to right.

Once they move their upper body back and forth one full cycle, their view avatar moves forward by about 0.5 m in the direction they are facing. Performing this gesture several times along the only available pathway in the snow brings them to a set of orientation activities that do not relate to realistic actions and objects that an Adélie penguin would encounter on Ross Island. One activity demonstrates moving objects in the environment using their beak. Another activity plays chimes when the objects are touched with a quick move from their flippers. At the edge of this orientation area where players learn to move, use their beak and flippers, lies a small bridge in the snow that spans a small stream flowing into the open ocean, as a symbol of moving from orientation into realistic engagements with penguin life (See Fig. 1).

The first interaction users encounter involves picking up small stones in the area and stacking them together to build a pile of stones that these penguins use as a nest for the eggs. Participants bend their back to lean down toward the ground and touching a stone with their beak connects it. If they waddle over to the nest and touch that area with their beak, the stone is released, and the nest grows larger. In another interaction, they act out a mating dance to pair with another penguin. In this activity, they move their head and body to touch visual indicators in their view in a specific sequence, similar to the well-known *Dance Dance Revolution* game mechanic. In the nesting interaction, participants are challenged to defend the egg in their nest from an incoming group of Skua birds, a natural predator to young Adélie penguins. Once positioned between the Skuas and their egg, they strike the predators with their flippers, as the actual Adélie penguins do, to defend their nest. By defending the egg from multiple Skuas for a predetermined amount of time, they complete the challenge. Success is rewarded with an animation of the birds retreating and the penguin's egg hatching.

3.2 Participants and Study Format

The study collected data from forty-three grade 3 through 8 (age 8 through 13) students, in groups of 10–20 from different informal learning organizations, attending a science festival on a major university campus. These groups were recruited in advance of the festival, being offered an opportunity to take part in a VR research project. Participants were brought into a separate space on a different floor of the facility where they were verbally introduced to the project and given a pre-experience questionnaire using a digital survey tool on their own mobile phone or using supplied iPad devices. From each group, eight participants at a time were moved into their own 3 m by 3-m square area then fit with a Meta Quest 2 virtual reality headset. The VR experience took approximately 20 min, then they completed a post-experience questionnaire.

3.3 Instruments and Data Preparation

The Dispositional Empathy with Nature scale [12] was used as a pre-experience questionnaire. This instrument contains nine Likert-scale items. A post-experience questionnaire instrument was developed to measure perceived embodiment in addition to the empathy measure used in the pre-experience questionnaire. Embodiment was measured using the Avatar Embodiment Questionnaire [2] which contains 25 Likert-scale items in subscales for body location, ownership, agency, motor control, and appearance.

From the data collected from 43 participants, 2 were dropped from analysis due to mismatching codes used to link the two questionnaires. 8 additional participants were dropped from comparison analysis due to missing empathy measures in the pre-experience questionnaire. Values for the Likert items were scaled so neutral responses = 0, minimum responses = –4, and maximum = 4.

4 Results

Results for the embodiment scores and empathy scores were plotted using histograms to ensure normally shaped results. Pairwise t tests were conducted on pre- and post-experience empathy scores to determine if a significant change in that score took place following the VR experience. Pearson's correlation was used to test for correlation between the post-experience embodiment and empathy scores. No outliers are seen in the embodiment nor empathy scores calculating z-values with a cutoff of 3 standard deviations.

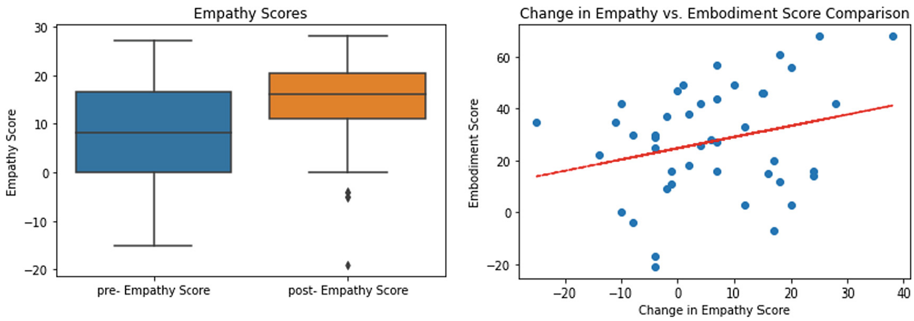

Fig. 2. A boxplot of the pre- and post-experience Empathy and a scatterplot of embodiment vs. change in empathy

To verify that the VR intervention was able to produce an experience of embodiment of a Adélie penguin we analyze the post-experience embodiment scores. The minimum possible score is -100 and the maximum possible score is 100. The mean embodiment score was 27.21 (std = 21.40), clearly in the positive range, which suggests an affirmative answer to RQ1, does the experience effectively produce an embodied experience of an Adélie penguin?

Empathy Score has a minimum possible score of -36 and a maximum of 36. A t test shows significant pre/post difference ($p = 0.0056$) increasing the mean score from 8.58 to 14.37 (see Fig. 2). This suggests an affirmative answer to RQ2, does the experience produce measurable increases in empathy for Adélie penguins?

Change in empathy scores were positively correlated with the participants' embodiment scores (see Fig. 2). Pearson's correlation coefficient is calculated to be 0.264, a low correlation. Calculating R-squared, we see that embodiment accounted for 7.0% of the variance in changes between pre- and post-experience empathy. This suggests an affirmative answer to RQ3, does increased embodiment correlate with an increase in empathy?

5 Discussion

This research demonstrates that design direct embodiment of a penguin is possible in VR, as shown by an overall positive score for this construct, which extends prior findings [10] and contributes to our understanding of designing VR for animal embodiment. This effect may be due to the visuomotor synchrony and gesture congruency afforded by the penguin skeleton. As penguins stand upright and have their flippers to the sides, a mapping of the participants arm location to flippers is possible. Additionally, this research demonstrates that a 20-min experience can increase children's situational empathy toward penguins. Finally, a correlational relationship was found between embodiment and empathy, with greater embodiment associated with increased changes in empathy, suggesting the relationship may be causal and should be further explored.

This research is limited by several factors. The sample size was small and drawn from a potentially biased population of attendees of a science festival. The measure of empathy was conducted within minutes of the experience and may not have any lasting effects. Finally, additional mediating factors between embodiment and empathy should be explored, potentially beginning with a predisposition to empathy with animals, previous knowledge about penguins, and comfort with Virtual Reality. The addition of a control group would aid in isolating these effects.

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