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Game-influenced methodology: Addressing child data attrition in language development research

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HIGHLIGHTS

- Task engagement impacts the efficacy of developmental research with preschoolers.
- Preschoolers in the gamified group outperformed the control group on task performance.
- Gamification of language-based task improves preschoolers' attention and engagement.
- Provides a beginning point for CCI using children's verbal responses as an interactive tool.

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ABSTRACT

Research on human development can be challenging for many reasons, one of which is high attrition rates for infants and children. To address the issues of attention and engagement, we examined whether gamification of an experimental methodology improved preschoolers' participation on a task. The Primed Picture-Naming Task (PPNT) has been widely used to study language processing in adults; however, few studies have successfully implemented the methodology with children under 5 years of age, in part due to children's difficulty in completing the task. One version of the PPNT incorporated narrative and goal-directed game-like elements, while the control version was presented in a traditional format. The results showed that preschoolers' participated longer and completed more trials compared to children in the control version. Gamification is a valuable tool for creating assessments of preschoolers' language development and for improving young children's motivation and engagement in research. This study provides a beginning point for the development of Child–Computer Interactions which use children's verbal responses as an interactive tool.

1. Introduction

Studying human development is challenging for many reasons, one of which is the high attrition rates for infants and children participating in experimental tasks [1–3]. While adults are able to focus their attention during long tasks, children require truncated versions. For example, experimental tasks with adults often last over 30 min, while experimental tasks for children are typically designed to last not more than 15 min. Moreover, adults and children cannot complete the same complexity of tasks, and tasks often need to be changed or simplified for younger participants (e.g., [4,5]). The difficulty of a task can also mask learners' abilities [6,7]. This makes comparisons between adults and children potentially difficult, since methodological changes can compromise the experiment's validity in testing the same phenomenon. Even if children are capable of completing a complex task, their performance can be influenced by attention and motivation [8]. One solution to address these issues is gamification, which has been defined as "the use of game design elements in non-game contexts [9, 9]". In this study, we examined whether gamification of an experimental methodology improved preschoolers' participation on a task. We used the Primed Picture-Naming Task (PPNT), which has been widely used to investigate language processing in adults. In this task, participants hear an auditory prime ('ball') followed by a target image which they name (BOOK). Researchers have had mixed success with the PPNT methodology to study language development. Moreover, few studies have successfully implemented the methodology with children under 5 years of age, in part due to children's attention and difficulty with completing the experimental task. In this study, we examine the effects of gamification on 2- to 4-year-old children's participation in the task by comparing two versions of a PPNT experiment. One version incorporated both narrative and goal-directed elements of game design, while the control version was presented in a simpler,

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more traditional format. The objective was to determine whether gamification of the PPNT impacted preschoolers' attention and engagement on the task. This study provides insight for Child–Computer Interactions as we explore children's performance in producing verbal responses to visual and audio computer prompts, across signal/communication modes.

1.1. Challenges and methodologies in developmental research

Rates of attrition and data loss in developmental research are consistently higher than in studies with adults. For example, Zamuner et al. [10] conducted the same word recognition experiment with adults and 2- to 3-year-olds. All of the adults completed the task, but 7% of the 2- to 3-year-olds did not. There is some variation on attrition and data loss with children depending on the type of methodology and age of children. For example, the word recognition study just described is an easy task to implement with young children and has relatively low attrition rates. However, more complex tasks such as the two-alternative forced-choice picture-matching task (2AFC) has much higher attrition rates with children the same age. Zamuner [11] reports that 65% of 2-year-olds run on the 2AFC were excluded from the analysis and Skoruppa, Mani and Peperkamp [12] report that 50% of 2- to 3-year-olds were excluded. A variety of reasons are provided for why the participants were excluded, such as failing to complete a pre-test, failing to complete the experimental task due to fussiness or lack of interest, and failing to complete enough experimental trials. Results can be skewed if there is an attrition bias, for example, if the youngest participants drop out of a control condition, but not a test condition, age becomes a confounding factor with the tested variable [8,13]. Skewed data requires complex statistical analyses [14] or testing more children to make up for lost data. Child participants may also complete only part of a study, and depending on the structure of the trial orders, this may cause an imbalanced number of data points in different conditions. For many methodologies, high rates of infants and children are excluded from studies due to fussiness or an inability to complete the experimental task. These high attrition rates indicate the necessity of revising designs to make them more appealing to children [1,3,13,15]. However, children's engagement cannot be entirely attributed to an inability to focus their attention or perform a repetitive task. When it is an activity that children enjoy, they can play for long periods of time, which can be extreme in some cases [16]. If experimental tasks can be made appealing, children should be more likely to complete the entire study. This would result in cleaner and more data to analyze, more efficient use of available participants, and a more positive experience for children.

In the field of language development, assessments are increasingly being administered with the use of computers and tablets [17]. This presents opportunities to improve methodological paradigms, reduce attrition rates, and improve attention and performance. Many research paradigms require controlled presentation of stimuli and timing of trials. By administering an experimental task on a computer or a tablet, experimenters can guarantee that the testing materials are the same for each child. To date, the majority of research looking at developmental speech production is longitudinal or uses off-line experimental methodologies. For example, children's speech production skills have been evaluated by looking at what words are added to children's vocabulary over time from data collected in naturalistic settings (e.g., [18,19]). Other experimental assessments of children's verbal language skills focus on global measures, such as analyzing children's responses as either correct or incorrect. These coarse-grained measures are not as sensitive compared to fine-grained, on-line or implicit measures of language processing [20]. An example of the difference between global versus fine-grained measures can be seen in the Picture Naming Task (PNT), where a child is asked to name the pictures, e.g., 'table' and 'piano'. Based on global measures, a 4-year-old will produce both words accurately. However, using fine-grained measures, there is actually a difference in how children perform on these trials; children generate or produce the early-acquired word 'table' faster than the late acquired word 'piano' [21]. The dependent measure used to calculate the speed of speech production is the speech reaction time (SRT): the mean naming latency or delay in milliseconds between the presentation of the image and the beginning of the utterance [22]. An adaptation of the PNT is the Primed Picture Naming Task (PPNT). In priming tasks, one stimulus (the prime) precedes another (the target). When the prime and target share an attribute (e.g., the same initial sound as in 'cat' and 'cow', or semantic features as in 'cat' and 'dog'), SRTs in the shared-attribute or 'related' condition are different than in the unrelated condition. The direction of the effect depends on the stimuli and the timing of the prime-target (e.g., [23,24]). In some studies, SRTs in the related condition are faster than in the unrelated condition which is called facilitative priming, and in other studies SRTs in the related condition are slower than in the unrelated condition and this is called inhibitive priming. Effects of priming in the adult literature are well established [25,26], and have provided many insights into how language is represented. For example, results from priming studies have revealed that our mental lexicon is an interconnected network with links between related words [27]. When we hear the word 'dog', our mental concept for 'dog' is activated, which in turn activates words related in sound (e.g., 'doll', 'dot', 'fog') and meaning ('cat', 'canine').

There are some published studies using SRT measures with typically developing children, children who stutter, and children with autism spectrum disorder, and results have typically reported facilitatory phonological priming effects (E.g., [28]). However, the existing handful of studies have almost exclusively been done with children aged 4 to 5 years and older [21,28–33], with no studies with children between 2 to 3 years of age. Data from these groups are important for education because the language skills acquired in the early preschool years form the basis for later literacy skills, such as reading and writing [34,35]. While the PPT and PPNT are promising methodologies for learning about children's language development, one of the central difficulties in using these methodologies is in engaging children in the task. In the literature, numerous studies have reported that preschoolers were not interested in participating in the task [21] and that attrition rates were due to "various maturational, attentional, and behavioral variables exhibited by 3–5-year-old children, [28]: 1432". Thus, the challenge of conducting the PPT and PPNT with young children makes these tasks a good choice for gamification, with the goal of improving children's attention, motivation, and engagement in the task. In addition, there are almost no experimental methodologies that are suitable to use with children under 3 years of age to examine on-line processing during speech production. The ability to implement the PNT and PPNT with this younger age group would enable researchers to examine how words are activated and processed during on-line speech processing.

1.2. Gamification

Gamification refers to "the use of game design elements in non-game contexts ([9]: 9)". Game-design elements are typically introduced to increase motivation and gamification has been applied to a variety of contexts, such as service and marketing, task management, and education [36–38]. See Deterding et al. [9] for a hierarchy of game design elements. Dondlinger [39] and Gee [40] describe different ways of increasing motivation and enjoyment for the player within an educational context, including the creation of an interesting story to frame the game; the inclusion of goal-focused elements such as a score, number of levels completed,

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