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Attributing Weight to Virtual Objects in Preschoolers

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Modern education is undergoing a process of digital transformation at all levels, including preschool. The psychologically founded use of digital technologies makes it relevant to study the child's ideas about the objects of the digital environment (virtual objects). This empirical study is aimed to test two hypotheses: 1) Preschoolers attribute the quality of weight to virtual objects; 2) Preschoolers perceive virtual objects as light-weighted. 53 children, 3.5 to 5 years old, participated in this study (M=4.3; SD=0.41). The study includes experimental technique (H. Kloos, E.L. Amazeen), assessed children's perception of weight based on their interaction with these objects without verbal self-report. The weight was operationalized through the location on a hill model (slope length — 40 cm) of two real objects (lightweight — 27 g, heavy — 170 g) and a virtual object, which was previously "lifted on the shelf" on a tablet PC screen. 92.5% of participants designated a specific place on the hill for the virtual object, suggesting they attributed weight to it. For 70.4% of children, the placement of a virtual object (Me=40 см) does not significantly differ (T_{emp}=13.5 p=0.933) from the placement of a light real object (Me=40см). For 18.2% of children, the placement of a virtual object (Me=14.5см) does not significantly differ (T_{emp}=11.5 p=0.673) from the placement of a heavy real object (Me=12.25см). Further research is necessary to better understand factors contributing to preschoolers' perception of virtual objects wight.

Keywords: weight perception, touchscreen, virtual object, attribution, preschoolers.

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Приписывание веса виртуальным объектам детьми дошкольного возраста

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Представленная статья основана на актуальных идеях о том, что современное образование переживает процесс цифровой трансформации на всех уровнях, включая дошкольный. Авторы считают, что психологически обоснованное использование цифровых технологий делает значимым исследование представлений ребенка об объектах цифровой среды (виртуальных объектах). Эмпирическое исследование было направлено на проверку двух гипотез: 1) дошкольники приписывают виртуальным объектам такое качество, как вес; 2) дошкольники идентифицируют виртуальные объекты как «легкие». В исследовании приняли участие 53 ребенка в возрасте от 3,5 до 5 лет (M=4,3; SD=0,41). В качестве инструмента работы применялся методический прием (Х. Клоос, Э.Л. Амазин), позволяющий выявить представления детей о весе предметов на основе результатов действий с этими предметами без словесного самоотчета. Вес был операционализирован через расположение на модели холма (длина — 40 см) двух реальных объектов (легкий — 27 грамм, тяжелый — 170 грамм) и виртуального объекта, с которым дети предварительно осуществляли действие «поднятие на полку» на экране планшетного компьютера. 92,5% детей указали определенное место расположения для виртуального объекта, то есть приписывали ему наличие веса. У 70,4% детей расположение виртуального объекта (Me=40 см) значимо не отличается ($T_{эмп}$=13,5, p=0,933) от расположения реального легкого объекта (Me=40 см), у 18,2% дошкольников расположение виртуального объекта (Me=14,5см) значимо не отличается ($T_{эмп}$=11,5, p=0,673) от расположения реального тяжелого объекта (Me=12,25 см). Отмечается, что необходима проверка дополнительных гипотез о факторах, влияющих на представление дошкольников о весе виртуальных объектов.

Ключевые слова: восприятие веса, тачскрин, виртуальный объект, приписывание, дошкольники.

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Introduction

The objective to update the preschool education system with new information technologies was formulated by the Ministry of Education of the Russian Federation over 20 years ago. The prospects of preschool education in the digital era are still of interest and are widely discussed by the scientific community [3; 5]. The psychologically informed use of digital devices requires an understanding of the nuances of children's perception of objects in a digital environment (virtual objects), and of the way it may differ from their perception of real life objects.

Various gaming applications are advertised as promoting development. This implies that the abilities, skills, and knowledge acquired using these applications are transferable and can be utilized to interact with real life objects. Such transfer is an important component of the learning process. The question is, to which extent the differences in perception of virtual and real objects can affect the quality of the transfer [4; 16].

Our recent study tested the hypothesis that children perceive virtual objects on a tablet PC screen as three-dimensional even though they interact with these objects by moving their fingers across a two-dimensional screen surface [10]. According to our results, 91% of children 4 to 6 years old perceive virtual objects as three-dimensional. At the same time, children miss out on shape details of virtual objects significantly more often than when they interact with real objects visually and visually-haptically.

Another property of virtual objects presumably perceived by children is weight. Unlike shape/size, weight cannot be directly perceived based on visual information. Unless deliberately provided with haptic feedback devices, haptic information about virtual objects is unavailable, driving the interest towards research on the perception of virtual objects' weight [8].

The study of formation of the concept of "weight" in children was initiated by E.J. Gibson [6] and J. Piaget [13]. Analysis of the related scientific publications leads to the following conclusions: 1) until a certain age, children do not differentiate between size and weight [6; 13]; 2) during development, the concepts of size, weight, and density undergo differentiation [15]; 3) felt weight is the core of the concept of weight in children under 7 years old [15]; 4) children of 8 to 9 years old conceptualize weight as a fundamental property of matter independent of feelings [15]; 5) the lower age limit for the formation of the concept of weight is 3—4 years [1; 15], however, infants are able to apply information about the relative weight of objects to their actions [7].

Since it is difficult for children under 7 years old to verbalize the properties of an object that is experienced as "heavy", there are methodological issues in studying weight perception in children of early and preschool age [1]. In order to eliminate lexical restrictions, a number of techniques free of verbal self-reporting have been proposed [9; 15]. One of them is called a "nonverbal weight task". It involves the creation of a game scenario where a child is asked to imagine to which observable consequences the interaction of objects of different weights with other game objects will lead. The advantage of this technique lies in shifting the focus from a visual, not directly observable property (weight) to clearly observable changes, as well as in eliminating the need for a child to use the word "heaviness" (weight, mass) which may be absent from his active vocabulary [9; 15].

In the scientific literature, virtual objects often model real objects rather than represent an independent class of objects with unique features. Thus, this research is exploratory in nature and is aimed to test two hypotheses: 1) Preschoolers attribute the quality of weight to virtual objects; 2) Preschoolers perceive virtual objects as light.

The first hypothesis was formulated from an experience-based learning approach. According to it, interaction with objects leads to the formation of associations between distinct properties of these objects (size, material, density, weight, category). These associations underlie expectations that allow the prediction of the weight of an unfamiliar object based on one or several known properties of it. Visual similarity between virtual objects and their real prototypes forms expectations about the weight of virtual objects on the basis of their perceived size and shape, similar to the perception of the weight of real objects associated with these properties.

The second hypothesis relies on the notion that estimates of an object's weight are linked to dynamic characteristics of interactions with these objects: objects that require less effort to move are seen as lighter objects. Movement of virtual objects across the tablet PC screen is carried out by sliding finger movements associated with light weight. Since our hypotheses are meaningfully related to the type of hypotheses about the presence of the phenomenon, the research plan did not include monitoring of object movement characteristics. Testing the causal hypothesis about the characteristics of movement as a factor in the perception of the weight of a virtual object represents one promising future research direction.

Subjects and procedure

53 children, 3.5 to 5 years old, participated in the present study (M=4.3; SD=0.41). The research procedure relies on a technique developed to study the "size-weight" illusion in preschoolers [9]. For the procedure, a schematic drawing of a hill with a house on top of it was made (Fig. 1).

Additionally, a computer application modeling a "lift onto a shelf" action was developed as most informative for estimating the weight of an object compared to other actions (Fig. 2). The application runs on the Android operating system. All the object models were created using the Blender three-dimensional computer graphics editor and imported into an application, written in Java using the LibGDX framework. The ap-

Fig. 1. A drawing of a hill used to locate objects of different weights
(the flag marks the position indicated by the child)

plication was installed on a Huawei tablet computer (model AGS2-L09).

Fig. 2. A photo of the tablet PC screen with the initial location of the virtual cube in relation to the shelf

The study was conducted as individual play sessions under the supervision of a psychologist from a preschool educational institution. The experimental procedure consisted of 4 stages.

1. *Explanation and demonstration*. Three polymer clay balls ("apples") with a diameter of 3.5 cm and a weight of 6, 40, and 83 grams (light, medium, and heavy) were made for the experiment. The psychologist tells a child a fairy tale about a mouse that lives in a house on a high hill. To stock up for the winter, she has to carry apples to the house on the hill. The psychologist hands the child the "heavy" ball and explains that if an apple were really heavy, it would be hard for the mouse to carry it to the top of the hill and she would have to take a rest. As a resting site, the psychologist points to a place near the base of the hill (5 cm). Similarly, for an apple of a medium weight, the resting site is located in the middle of the hill (20 cm), and for a light apple it is on the top of the hill (40 cm).

2. *Checking understanding of information about weight*. The psychologist gives the child the heavy and then the light "apple" and asks the child to show where the mouse would take a rest.

3. *The main stage with real objects*. The psychologist presents a new fairy tale scenario (a mouse that is carrying three pieces of cheese to her house). As "pieces of cheese", 4 polymer clay cubes with a length of 4 cm are used. They vary in weight: light (27 g), medium (80 g), and heavy (170 g). At the beginning of this and the following experimental stages, the psychologist hands the child a cube of a medium weight and shows that the mouse carrying this cube would stop for a rest in the middle of the hill (20 cm). Then the child is given a heavy and a light cube. The psychologist asks the child to point to the place on the hill where the mouse would stop to rest. As a control for the sequence effect, half the participants (27 children) were presented with the light cube prior to the heavy cube, and the other half (26 children) were presented with the heavy cube prior to the light cube.

4. *The main stage with virtual objects*. The psychologist shows the child a cube and a shelf on a tablet PC screen and explains that this "piece of cheese" (a cube with a length of 1.7 cm) was sent to the mouse by mail. The child is asked to place the cube on the shelf, moving it across the tablet PC screen. The child completes the "lift the cube onto the shelf" action 2—3 times. Then, the psychologist asks the child to point to the place on the hill where the mouse would stop to rest when she would be carrying home this "parcel of cheese".

The results of the third and fourth main stages were represented by three indicators: the placement of the heavy and the light real cubes, and the placement of the virtual cube (the distance from the hill base, cm). The placement of the heavy and the light real cubes are considered to be correlates of the child's weight estimates for these objects: heavier objects were placed closer to the hill base, while lighter objects were placed closer to the hilltop. The placement indicators of the light and the heavy real cubes were used as reference points to quantify the child's weight estimate of the virtual cube. Statistical data analysis was carried out in Statistica 6.0.

Results

During the processing of the data array (53 children), the results of 5 children were excluded as there was no significant difference between their placement of the heavy and the light real cubes, together with the results of 4 other children who could not answer the question about the placement of the virtual cube ("I don't know").

The results from the rest of the children were sorted into three groups based on the placement of the virtual cube in relation to the real cubes: group 1 ("light") — closer to the light cube (31 participants), group 2 ("heavy") — closer to the heavy cube (8 participants), group 3 ("uncertain") — in between of the light and the heavy cube (5 participants) (Table 1, fig. 3). To assign the value of the placement of the virtual cube to a certain group, rather than an objective scale (0—40 cm), subjective scales were used, determined by the individual values of the placements of the light and heavy real cubes for each child.

Table 1

Placement of the real and the virtual cubes as indicators of weight estimates

Group	Number of children	Weight-based identification of the virtual cube	Real cubes				Virtual cube (V)	
			Heavy (RH)		Light (RL)			
			Range (cm)	Median (cm)	Range (cm)	Median (cm)	Range (cm)	Median (cm)
1	31 (70.4%)	light	0—30	9	21—40	**40**	33—40	**40**
2	8 (18.2%)	heavy	4—30	**12.25**	40—40	40	5—28	**14.5**
3	5 (11.4%)	uncertain	0—14	9	40—40	40	22—27	23

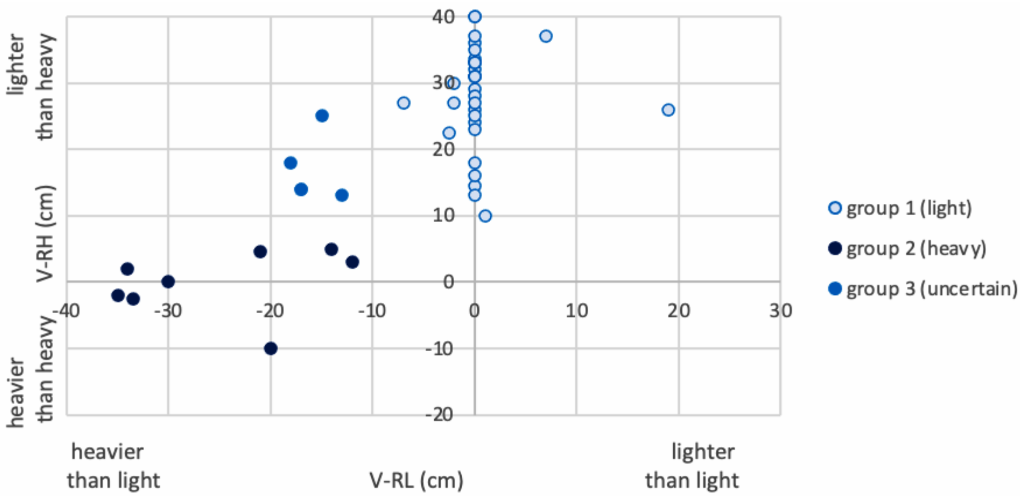

Fig. 3. Individual indicators of the virtual cube placement in relation to the light and the heavy real cubes

Based on an analysis of the results, we confirmed our first hypothesis. A child would not be able to accomplish the task of choosing a specific location on the hill for the virtual object presented without perceiving it as having weight. Of 53 participants, 49 (92.5%) accomplished the task, implying that children attribute the property of weight to virtual objects.

To test the second hypothesis, the distribution of the frequency of choice of position for the virtual cube was compared to a uniform distribution using Pearson's chi-squared test. The resulting value χ^2_{emp}=27.59 ($p \leq 0.001$) shows statistically significant discrepancies between the distributions. Thus, the choice by the majority of the children of a position for the virtual cube that is close to the position of the light real cube is not accidental. It suggests that the virtual cube is identified as a light cube.

For both of groups 1 and 2 ("light" and "heavy", respectively), the reliability of the shift in the value of the position of the virtual cube in relation to the position of the real cubes was assessed using the Wilcoxon T-test. For 70.4% (group 1) of children, the placement of a virtual object (Me=40cm) does not significantly differ (T_{emp}=13.5 p=0.933) from the placement of a light real object (Me=40cm). For 18.2% of children (group 2), the placement of the virtual object (Me=14.5cm) does not significantly differ (T_{emp}=11.5 p=0.673) from the placement of a heavy real object (Me=12.25cm).

Discussion

Kloos and Amazeen developed a research technique for identifying a real object's weight without verbal self-report [9]. It enables us to study the ability of preschoolers to compare different weight gradations in the perception of real and virtual objects.

Virtual object manipulation lacks realistic haptic feedback [8]. Nevertheless, preschoolers tend to attribute to virtual objects those properties of real objects that can be directly perceived through haptic feedback. Likely, the transfer of the properties of real objects to virtual ones facilitates a child's exploration of virtual reality. The results of our study of weight attribution to virtual objects in preschoolers are consistent with the results of the study of personal 'theories' about mass that examines the understanding of mass of drawn objects in 4-to 6-year-old children [12].

Our results are also in agreement with the conclusions of Russian [1; 2] and foreign [11; 14] psychologists regarding the role of active sensorimotor interactions with real objects for the development of a child's perceptual abilities, as well as for the ability to predict the physical characteristics of visually perceived objects. In addition, we showed that the experience obtained as a result of a child's interaction with real objects (memory-based representations about the properties of objects) can be transferred to the perception of virtual objects.

The main result of this study was that the specifics of weight attribution to virtual objects by preschoolers were identified. Taking our previous study [10] into account, we propose that children perceive virtual objects as three-dimensional (often missing out on shape details) and possessing the property of weight (often perceived as light).

Besides the small sample size, the limitations of this study lie in the differences between the conditions for presenting the real and the virtual objects, such as the objects' size and movements when interacting with them. The experimental procedure does not provide an exact quantitative correlation of the positions of the real and the virtual objects but rather defines the general rule: the bottom part of the hill is for the heavier objects, the top part is for the lighter ones. Nonetheless, the differences noted in object presentation may cause reduced validity.

Given the associations between weight and other sensory features [18], further research should be aimed at investigating factors determining the perceived weight of virtual objects, such as movement characteristics when interacting with these objects (less force applied/ more force applied), and visually perceived characteristics (size, density).

Conclusions

1. The results of this study support our hypothesis that preschoolers attribute weight to virtual objects. Weight attribution may be shaped by the association of the visually perceived properties of real objects and their weight, formed during interactions with these objects, as well as by the visual similarity of virtual objects with their real prototypes, which simplifies the perceptual transfer of real objects' properties to virtual objects.

2. Preschoolers identify virtual objects as light significantly more often than as heavy. We speculate that the characteristics of a virtual object's movement during interaction with it is one of the factors shaping the weight perception of such an object. To test this, kinematic the characteristics of the virtual object movement have to be monitored together with the alternation in the perceived weight of the virtual object (for example, using visual delay [17]).

3. The present research belongs to the field studying the cognition of virtual objects as a unique class of objects, and draws attention to the necessity to expand the scope of interest in cognitive psychology beyond physical reality.

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