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Human–Human Versus Human–Robot Interaction in Piaget's Liquid and Mass Conservation Performed by 5–6-Year-Old Children

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Abstract

This research emphasizes the importance of human–robot interaction in psychology of cognitive development. In the experiments conducted, the hypothesis that children's cognitive comprehension is enhanced by using a robotic experimenter to guide them through the tasks, instead of a human one, was tested. Quantity conservation conceptualization in children aged 5–6 years old was examined by utilizing the Piagetian conservation of liquid and mass tasks, via the use of an electronic tablet device and a robot. The participants were 160 first graders (equal gender representation). Half of the children executed the experiments with a robot experimenter, while the other half executed the experiments with a human experimenter. Two distinct sets of tasks were used. For the conservation of mass, a clay sphere was turned into a lengthy structure, while the conservation of liquid was performed by pouring water from a short-wide glass to a long-narrow one. Pictures, graphics, and sound were used to clarify what was occurring. The results of children guided by a robot experimenter were compared to the results of children guided by a human experimenter, as traditionally conducted. This study reveals that children performed better and were more likely to perceive the concept of conservation when they interacted with a robot experimenter. The evident psychological and educational implications are discussed.

Keywords: Cognitive development, Human–robot interaction, Liquid conservation, Mass conservation, Piaget, Psychology

1. Introduction

Several researchers have investigated the applicability of Piaget's theory of cognitive development. Among his many achievements, Piaget discovered that children between the ages of 5 and 8 understand the logical idea of conservation. Conservation tasks have received the most extensive investigation of any Piagetian assignment. A given set of achievements coincide with a specific age following Piaget's stages of cognitive development. According to Piaget, children do not develop meaningful operational skills until they are 7 years old (Babakr et al., 2019). As a result, children start to think rationally and conclusively around the age of 7. Children use tangible representations to address problems throughout this time. They continuously come into contact with new experiences, objects, and words owing to their rapid advances in motor ability and linguistic development. When they are faced with something new, they can either assimilate it into an existing schema by matching it with what they already know or expand their knowledge structure to fit the new scenario, covering the major developmental theories. Many of the children's preexisting schemas will be tested, enlarged, and rearranged during this stage. Conservation presents the most difficulty during the concrete operating phase (Nambeye, 2020).

Despite making significant contributions to the corpus of knowledge concerning intelligence, Piaget has received criticism, which is crucial to highlight (Lourenço & Machado, 1996). Contemporary but also older researchers have indicated that children possess many abilities at an earlier age than was identified by Piaget. Young children may be more capable of thought than originally thought (Gruen, 1965). Most of the critics focus on the methodology of the "clinical method of Piaget." This procedure can cover the real cognitive capacities of young children, putting them into an uncomfortable and even stressful condition facing the experimenter, who is usually an "expert" adult with concrete expectations of them. Children try to recognize the communicative intention of the experimenter from the global condition, that is, the verbal and the nonverbal information, as it is described in cognitive linguistics by relevance theory (Chapelle, 2019). Furthermore, according to critics concerned especially with Piaget's conservation tasks, asking a child a similar question more than once is a blatant indication that the initial response was incorrect. As a result, researchers discovered that some 6-year-olds provided the right response whenever they replicated Piaget's tasks and only posed the question after the transition was performed (Light, Buckingham, & Robbins, 1979). Other academics criticized Piaget's assignment on quantity conservation, arguing that alterations made by adults led children to perceive that the modification was just as significant. Therefore, researchers developed an experiment on conservation of number that was comparable to Piaget's (McGarrigle & Donaldson, 1974). The researchers confused the counts whenever they stretched out the column of counters using the "Naughty Teddy Bear," making the shift appear unintentional. Over 62% of children responded affirmatively when asked if the candies in the first and second rows were comparable, higher than the response rate of less than 15% from Piaget's research.

Although some academics have criticized Piaget's findings, experiments conducted by other academics such as Elkind (1967) have shown that this is not the case. Elkind highlighted Piaget's research on American children between the ages of 5 and 6 (Watanabe, 2020). These findings supported Piaget's theories on conservation tasks, showing that the capacity for conservation dramatically rises with age. Thus, various research has been conducted on conservation and the age that children become aware of it.

An analysis of the numbers, mass, weight, and volume developmental sequencing in children was the aim of a similar study. The researcher's primary goal was to determine the period at which children could perform the aforementioned conservation tasks. Over 159 primary school students between the ages of 4 and 11 participated in the research (Nambeye, 2020). To determine whether conservation starts as soon as 4 years old, researchers tried to include children as young as that age who were in the preoperational stage. The findings were consistent with Piaget's claims that the children showed a similar sequential accomplishment of conservation of numbers, mass, weight, and volume. Children from the conventional and solid operational levels were examined in the research. In another study (Kim, 1987), the factors that could impact conservation were examined. Two hundred kindergarten students were included in the study, whose ages varied from 4 to 8 years, with an average of 5 years. Among the overall population, 55% were boys and 45% girls. The findings indicated age as a principal factor of conservation capacity and that children aged 6 or older performed noticeably better than those aged under 6. Another important study (Goldschmid et al., 1973) was performed to evaluate the order and speed of conservation knowledge acquisition in a variety of children between the ages of 4 and 8 across different countries. The Concept Assessment Kit-Conservation (De Vries et al., 1969) was used, and 250 children from six countries—Australia, Holland, England, New Zealand, Poland, and Uganda—made up the sample. According to the research, there were only a few differences in the rate of accumulation, which were presumably caused by different environmental factors. Age and the capacity to conserve were also relatively constant in males and females. Recent research (Watanabe, 2019) has also shown the influence of affective factors on the acquisition of the conservation concepts.

In the research presented in this article, the conservation concept is studied using the well-known Piagetian conservation tasks of liquid and mass, but with a substantial shift: the introduction of a robot experimenter instead of a human. Robots nowadays are becoming sharper and more advanced nearly every day. Robotic systems may soon be moving from the production line into our residences and even taking care of the children, thanks to recent developments in artificial intelligence and software algorithms. Nonhumanoid and mainly humanoid Socially Assistive Robots are used to improve children's creativity, motivation, and social skills (Ali et al., 2019; Masson et al., 2017). Harvard University researchers have also entered the field of child-friendly robotics (Rubenstein et al., 2015). They started developing a cheap robot in 2014 that could be readily controlled utilizing an application and a basic programming system. Any institution might utilize such robotics to inspire students to learn to program. Future generations will see more and more robots in daily life. It has been demonstrated that engaging students with robots in the classroom increases understanding. According to Solace Shen, a Cornell University psychologist specializing in developing young children and experiments on robot–human interrelations, contemporary research indicates that children could benefit from communicating with robotics (Bennington-Castro, 2017), and they can learn by teaching robots, improving linguistic, reading, writing, reasoning, and other cognitive capacities (Jamet et al., 2018). It is possible that among the first jobs that child-friendly robots will do is helping preschool instructors. Researchers are investigating the potential use of robotics in classrooms with children as part of studies (Leite et al., 2012). According to extensive literature available, children with special needs are drawn to robotics because they are less complicated and unpredictable than individuals, less frightening, endlessly patient and constant in their voice quality and attitude, and extremely configurable and adaptive to the requirements of individual children. Most of these values can be transferred to typically developed children and ease the adjustment period for experiments and provide more accurate results.

Therefore, in this study the hypothesis is that using a robot experimenter would aid in knowledge and understanding of the conservation concept, eliminating the human experimenter bias as previous academics have noted. Another objective of this research was to identify possible associations between the acquisition of the general concept of conservation and three more specific concepts, identity, compensation, and reversibility. These concepts are considered by Piaget to be easier to understand by children because they are based on perception, in comparison to the concept of conservation that is based on reasoning. Therefore, they are normally acquired before the conservation concept (Hooper, 1969; Piaget & Inhelder, 1974). Considering all the circumstances mentioned herein and empirical findings supporting that the vast majority of children develop into Partial Conservers for liquid and mass throughout this period (Church & Goldin-Meadow, 1986), three developmental phases are anticipated to occur between those ages: children who continuously identify the conservation concept (Total Conservers, TC), those doing so to a limited extent (Partial Conservers, PC), and children who do not (Non-Conservers, NC).

2. Method

2.1 Participants

The participants were 160 first graders from public and private institutions. Participants ranged in age from 5 to 6 years old, an age group whose developmental growth is thought to be incomplete. There were no apparent disparities in the children's developmental stage or socioeconomic status, and everyone was in good health. All operations were carried out with the guardians' and the institutions' administrations' full knowledge and approval. Moreover, the children verbally agreed to participate in the research. Every participant was required to answer five introductory questions before being accepted in the study to ensure that an understanding of basic concepts existed. Results from children who did not answer at least four out of five introductory questions correctly were not considered. The introductory questions were:

• Which glass holds more, a large or a small one?

• Which is bigger, the truck or the taxi?

• Which glass has less in it, one full or one empty?

• Which is higher, the roof of the apartment building or the sidewalk?

• Which is wider, a plate or a glass?

2.2 Research Design

The experiment consisted of two consecutive conservation tests based on the Piagetian conservation tasks and developed on tablet devices. Each test consisted of four separate tasks, the first one concerned with the general concept of conservation and the three others with the more specific concepts of identity, compensation, and reversibility. One of the tests was based on liquid conservation, and the other one was based on mass conservation. Visual instructions were presented to the participants via the tablet device. Each task was structured in three different stages presenting to the participant one unique image, either static or animated. The last stage also contained three buttons on screen that were used to provide the answer by pressing them. The buttons were MORE, LESS, and EQUAL, and their order of appearance was randomized each time a task was presented. Audio instructions accompanied each task stage, either from the human or the robot experimenter. Half of the study participants received guidance from humans (human–human interaction), and the other half received guidance from a robot (human–robot interaction) without any human presence or human interaction. The audio instructions were predefined and the same for the two groups. Except from the instructions for each task stage, some encouraging phrases were prepared in case some children needed motivation to continue with the experiment. Such phrases were: "What do you think, you haven't told me yet," "Try to find the answer, you can do it!", "We agreed to help me understand, let's continue," "Do you want to see it again, or should we proceed?". The robot used for the experiments was EZ-Robot JD Humanoid, a humanoid robot built to be accessible to users and suitable for educational and other purposes (Mubin et al., 2013). It has many features such as motion and sound output. Its movements range from simple hand movements to complex movements that use all the robot's joints. The robot dimensions are 15 cm long, 13 cm wide, and 33 cm high, and it weighs 1.33 kg (Figure 1). To maintain the attention and interest of the children, the robot could perform some simple movement actions such as wave of hand, bow, head scratch, and hand movement.

Figure 1. Robot Experimenter Used in the Tests

To achieve complete understanding of the experiment, a detailed description of each test, task, and stage follows:

- Liquid conservation – Task 1

The first task of the liquid conservation test concerned the general concept of conservation. The visual guidance is depicted in Figure 2. Stage 1 presented a static image with two identical glasses, stage 2 presented an animated image showing the person picking up one glass and pouring water from one glass to a different one, and stage 3 presented a static image again with the two glasses. The audio guidance was provided by the phrases "We have those two glasses of water" for stage 1, "We pour water from one glass to the other" for stage 2, and finally "Now, does the new glass have the same amount as, less than, or more than the amount of water from the first one?".

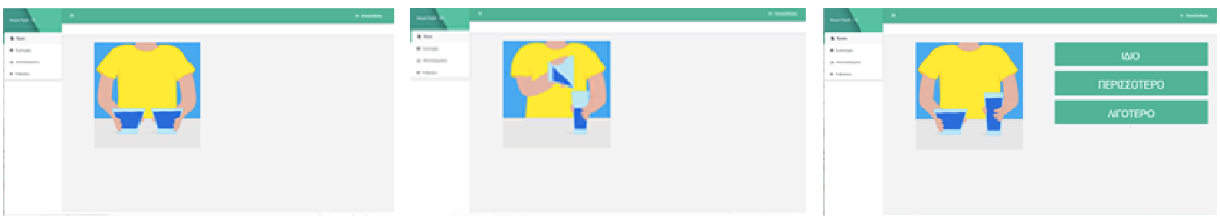

Figure 2. General Concept of Liquid Conservation

- Liquid conservation – Task 2

The second task of the liquid conservation test concerned the concept of identity. The visual guidance was the same as Task 1, depicted in Figure 2. Stage 1 presents a static image with two identical glasses, stage 2 presents an animated image showing the person picking up one glass and pouring water from one glass to a different one, and stage 3 presents a static image again with the two glasses. The audio guidance was provided by the phrases "We have those two glasses of water" for stage 1, "We pour water from one glass to the other. We didn't add additional water, only the one that existed" for stage 2, and finally "Now, does the new glass have the same amount as, less than, or more than the amount of water from the first one?".

- Liquid conservation – Task 3

The third task of the liquid conservation test concerned the concept of compensation. The visual guidance was the same as Task 1, depicted in Figure 2. Stage 1 presents a static image with two identical glasses, stage 2 presents an animated image showing the person picking up one glass and pouring water from one glass to a different one, and stage 3 presents a static image again with the two glasses. The audio guidance was provided by the phrases "We have those two glasses of water" for stage 1, "We pour water from one glass to the other. Be careful, the new glass is taller and narrower" for stage 2, and finally "Now, does the new glass have the same amount as, less than, or more than the amount of water from the first one?".

- Liquid conservation – Task 4

The fourth task of the liquid conservation test concerned the concept of reversibility. The visual guidance is depicted in Figure 3. Stage 1 presents a static image with two identical glasses, stage 2 presents an animated image showing the person picking up one glass and pouring water from one glass to a different one, and stage 3 presents an animated image showing the person picking up the new glass and pouring the water in the old glass again. The audio guidance was provided by the phrases “We have those two glasses of water” for stage 1, “We pour water from one glass to the other” for stage 2, and finally “Now, we pour the water back again. Is the amount of water the same, less, or more than it was at first?”.

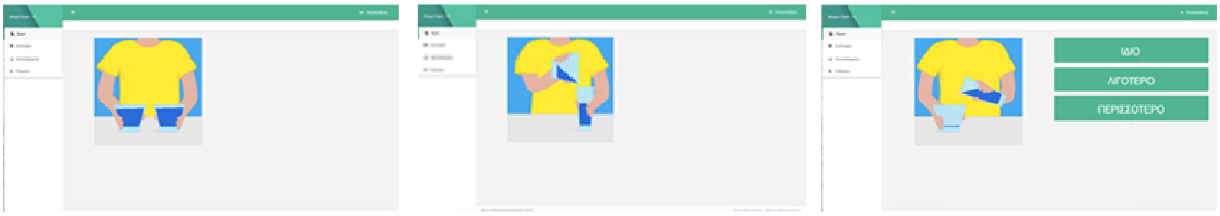

Figure 3. Reversibility Concept of Liquid Conservation

- Mass conservation – Task 1

The first task of the mass conservation test concerned the general concept of conservation. The visual guidance is depicted in Figure 4. Stage 1 presents a static image with two identical spheres, stage 2 presents an animated image showing the person picking up one sphere and transforming it into a lengthy structure, and stage 3 presents a static image again with the sphere and the lengthy structure. The audio guidance was provided by the phrases “We have two identical clay balls” for stage 1, “With one clay ball we create a cylinder” for stage 2, and finally “Now, does the cylinder have the same amount of clay, more, or less?”.

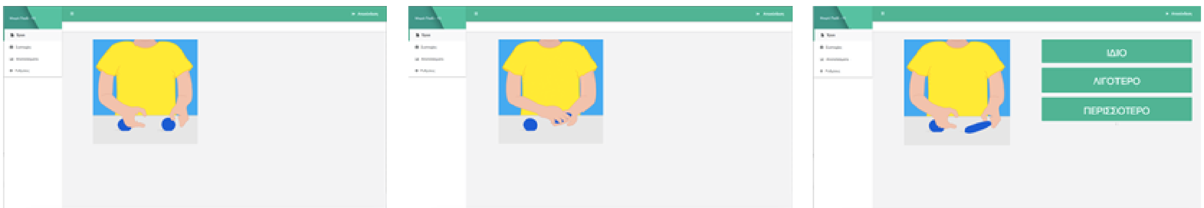

Figure 4. General Concept of Mass Conservation

- Mass conservation – Task 2

The second task of the mass conservation test concerned the concept of identity. The visual guidance is the same as Task 1, depicted in Figure 4. Stage 1 presents a static image with two identical spheres, stage 2 presents an animated image showing the person picking up one sphere and transforming it into a lengthy structure, and stage 3 presents a static image again with the sphere and the lengthy structure. The audio guidance was provided by the phrases “We have two identical clay balls” for stage 1, “With one clay ball we create a cylinder. We didn’t add additional clay, only what already existed” for stage 2, and finally “Now, does the cylinder have the same amount of clay, more, or less?”.

- Mass conservation – Task 3

The third task of the mass conservation test concerned the concept of compensation. The visual guidance is the same as Task 1, depicted in Figure 4. Stage 1 presents a static image with two identical spheres, stage 2 presents an animated image showing the person picking up one sphere and transforming it into a lengthy structure, and stage 3 presents a static image again with the sphere and the lengthy structure. The audio guidance was provided by the phrases “We have two identical clay balls” for stage 1, “With one clay ball we create a cylinder. Be careful, the cylinder is longer but narrower” for stage 2, and finally “Now, does the cylinder have the same amount of clay, more, or less?”.

- Mass conservation – Task 4

The fourth task of the mass conservation test concerned the concept of reversibility. The visual guidance is depicted in Figure 5. Stage 1 presents a static image with two identical spheres, stage 2 presents an animated image showing the person picking up one sphere and transforming it into a lengthy structure, and stage 3 presents an animated image showing the person transforming the lengthy structure into a sphere again. The audio guidance was provided by the phrases “We have two identical clay balls” for stage 1, “With one clay ball we create a cylinder” for stage 2, and finally “With the cylinder we create a ball again. Does the ball have the same amount of clay, more, or less than the one we had at first?”.

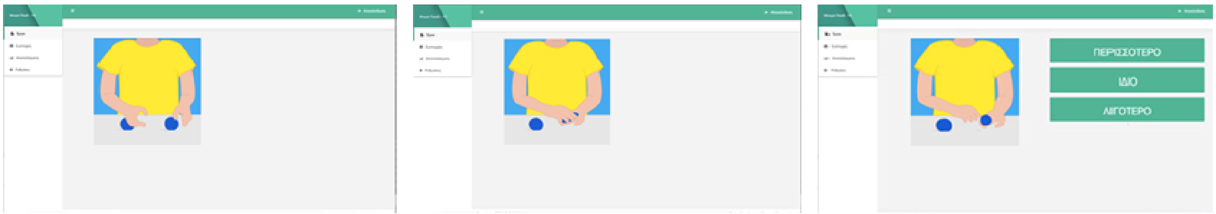

Figure 5. Reversibility Concept of Mass Conservation

2.3 Procedure

One child at a time took part in an experimental process that lasted around 20–30 minutes during a typical afternoon. The research was conducted in education centers located in Athens, Greece in appropriately designed rooms to meet the necessary conditions. Every child participating sat at a table, addressing either the human experimenter or the robot experimenter, and had a tablet right in front of them. Both the human and the robot experimenters were at a distance on the opposite side of the table. More specifically, when the experimenter was the robot there was no visible contact between the child and the human operating the robot. The child was monitored via a specially placed camera, which showed in real time what was happening in the room on a screen accessible by the robot's human operator. The children received no feedback on their answers during or after the experiment. Finally, the children participated anonymously in the research, so each subject was assigned a random ID number, and every answer that was given in the tablet device was stored in the database for further analysis, associated only with this ID number.

3. Results

The data were analyzed using IBM SPSS Statistics (Version 26). Table 1 demonstrates the results of liquid conservation tests, and Table 2 demonstrates the results of mass conservation tests. Both tables are split by experimenter, robot, and human. A correct answer was considered when the child pressed the button "EQUAL" on the tablet device, while a wrong answer was considered when the child pressed either the button "MORE" or the button "LESS." In each cell there is the absolute number of answers followed by the percentage of total participants in each task.

Table 1. Liquid Conservation Test Results

Experimenter	Answers	General (n=80)	Identity (n=80)	Compensation (n=80)	Reversibility (n=80)
Robot	Correct	50 (62.5%)	57 (71.3%)	53 (66.3%)	52 (65.0%)
	Wrong	30 (37.5%)	23 (28.8%)	27 (33.8%)	28 (35.0%)
Human	Correct	38 (47.5%)	48 (60.0%)	47 (58.8%)	47 (58.8%)
	Wrong	42 (52.5%)	32 (40.0%)	33 (41.3%)	33 (41.3%)

Table 2. Mass Conservation Test Results

Experimenter	Answers	General (n=80)	Identity (n=80)	Compensation (n=80)	Reversibility (n=80)
Robot	Correct	45 (56.3%)	50 (62.5%)	54 (67.5%)	55 (68.8%)
	Wrong	35 (43.8%)	30 (37.5%)	26 (32.5%)	25 (31.3%)
Human	Correct	41 (51.3%)	50 (62.5%)	50 (62.5%)	46 (57.5%)
	Wrong	39 (48.8%)	30 (37.5%)	30 (37.5%)	34 (42.5%)

To better analyze these results, the number of correct answers for each concept of conservation was plotted in a bar chart. By looking at the chart (Figure 6), it is easy to notice that the general concept of conservation in both tests (liquid in blue color, mass in yellow color), for both experimenters, has a lower number of correct answers compared to the identity, compensation, and reversibility tasks.

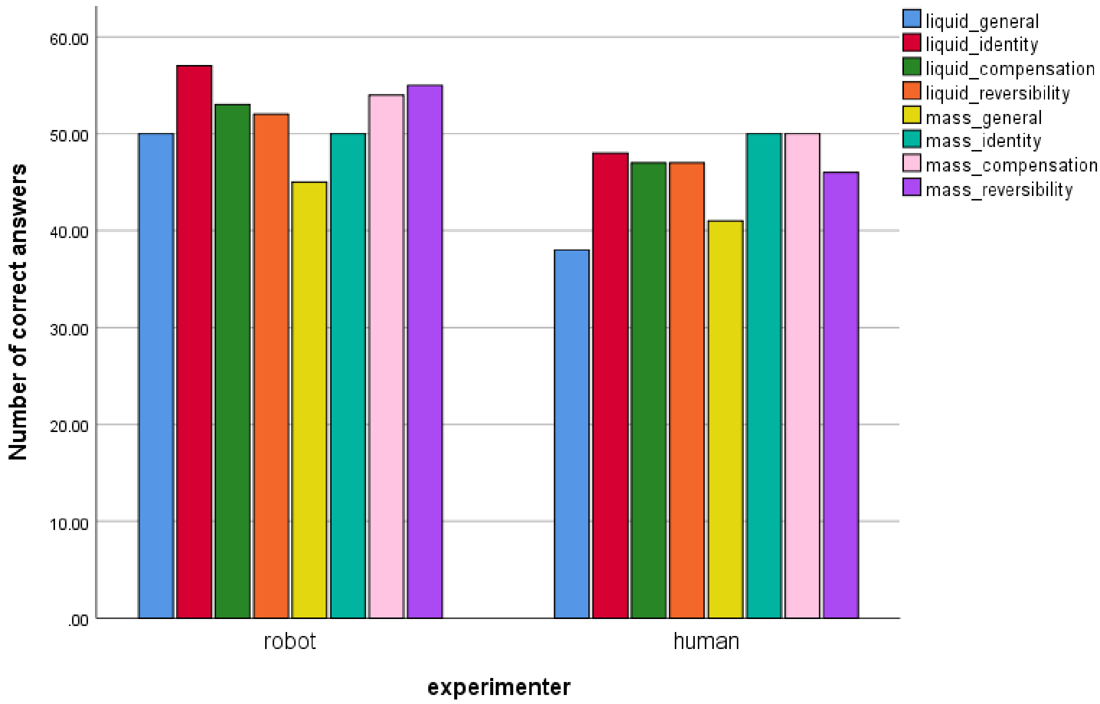

Figure 6. Correct Answers for Each Conservation Task's Results.

Following that observation, chi square test of independence was performed to check for possible associations between the general concept of conservation and each of the three specific concepts. Bonferroni correction was used to determine the acceptable p value, which was calculated to be 0.004 (0.05/12). In general, no cases had significant statistical association ($p<0.004$), thus with those sample sizes and age group of children we cannot confirm any overall association among the tasks.

For liquid conservation tests performed by the robot experimenter:

- Out of 50 children who answered correctly to the general concept of conservation, 37 answered also correctly to the identity concept and 13 answered wrong. Out of 30 children who answered wrong to the general concept of conservation, 10 answered also wrong to the identity concept and 20 answered correctly. No significant association between the two concepts was found, $x^2(df=1, N=80) = 0.492$, $p = 0.483$.
- Out of 50 children who answered correctly to the general concept of conservation, 36 answered also correctly to the compensation concept and 14 answered wrong. Out of 30 children who answered wrong to the general concept of conservation, 13 answered also wrong to the compensation concept and 17 answered correctly. No significant association between the two concepts was found, $x^2(df=1, N=80) = 1.972$, $p = 0.160$.
- Out of 50 children who answered correctly to the general concept of conservation, 36 answered also correctly to the reversibility concept and 14 answered wrong. Out of 30 children who answered wrong to the general concept of conservation, 14 answered also wrong to the reversibility concept and 16 answered correctly. No significant association between the two concepts was found, $x^2(df=1, N=80) = 2.872$, $p = 0.090$.

For liquid conservation tests performed by the human experimenter:

- Out of 38 children who answered correctly to the general concept of conservation, 20 answered also correctly to the identity concept and 18 answered wrong. Out of 42 children who answered wrong to the general concept of conservation, 14 answered also wrong to the identity concept and 28 answered correctly. No significant association between the two concepts was found, $x^2(df=1, N=80) = 1.637$, $p = 0.201$.
- Out of 38 children who answered correctly to the general concept of conservation, 23 answered also

correctly to the compensation concept and 15 answered wrong. Out of 42 children who answered wrong to the general concept of conservation, 18 answered also wrong to the compensation concept and 24 answered correctly. No significant association between the two concepts was found, x^2(df=1, N=80) = 0.942, p = 0.759.

- Out of 38 children who answered correctly to the general concept of conservation, 24 answered also correctly to the reversibility concept and 14 answered wrong. Out of 42 children who answered wrong to the general concept of conservation, 19 answered also wrong to the reversibility concept and 23 answered correctly. No significant association between the two concepts was found, x^2(df=1, N=80) = 0.580, p = 0.446.

For mass conservation tests performed by the robot experimenter:

- Out of 45 children who answered correctly to the general concept of conservation, 29 answered also correctly to the identity concept and 16 answered wrong. Out of 35 children who answered wrong to the general concept of conservation, 14 answered also wrong to the identity concept and 21 answered correctly. No significant association between the two concepts was found, x^2(df=1, N=80) = 0.166, p = 0.684.
- Out of 45 children who answered correctly to the general concept of conservation, 34 answered also correctly to the compensation concept and 11 answered wrong. Out of 35 children who answered wrong to the general concept of conservation, 15 answered also wrong to the compensation concept and 20 answered correctly. No significant association between the two concepts was found, x^2(df=1, N=80) = 3.043, p = 0.081.
- Out of 45 children who answered correctly to the general concept of conservation, 36 answered also correctly to the reversibility concept and 9 answered wrong. Out of 35 children who answered wrong to the general concept of conservation, 16 answered also wrong to the reversibility concept and 19 answered correctly. No significant association between the two concepts was found, x^2(df=1, N=80) = 6.059, p = 0.014.

For mass conservation tests performed by the human experimenter:

- Out of 41 children who answered correctly to the general concept of conservation, 30 answered also correctly to the identity concept and 11 answered wrong. Out of 39 children who answered wrong to the general concept of conservation, 19 answered also wrong to the identity concept and 20 answered correctly. No significant association between the two concepts was found, x^2(df=1, N=80) = 4.086, p = 0.043.
- Out of 41 children who answered correctly to the general concept of conservation, 29 answered also correctly to the compensation concept and 12 answered wrong. Out of 39 children who answered wrong to the general concept of conservation, 18 answered also wrong to the compensation concept and 21 answered correctly. No significant association between the two concepts was found, x^2(df=1, N=80) = 2.432, p = 0.119.
- Out of 41 children who answered correctly to the general concept of conservation, 27 answered also correctly to the reversibility concept and 14 answered wrong. Out of 39 children who answered wrong to the general concept of conservation, 20 answered also wrong to the reversibility concept and 19 answered correctly. No significant association between the two concepts was found, x^2(df=1, N=80) = 2.402, p = 0.121.

The next step was to perform the analysis to determine whether the robot experimenter yielded better results than the human experimenter. Chi square test of independence was performed in each concept of conservation to check the association between the robot and human experimenters. Although the tests performed by the robot experimenter presented a slightly larger number of correct answers, there was no significant association between the experimenters in every case. The exact number of correct and wrong values can be found in Table 1 for liquid conservation and Table 2 for mass conservation. The chi square analysis results are:

- For the general concept of liquid conservation: x^2(df=1, N=80) = 3.636, p = 0.057
- For the identity concept of liquid conservation: x^2(df=1, N=80) = 2.244, p = 0.134
- For the compensation concept of liquid conservation: x^2(df=1, N=80) = 0.960, p = 0.327
- For the reversibility concept of liquid conservation: x^2(df=1, N=80) = 0.662, p = 0.416
- For the general concept of mass conservation: x^2(df=1, N=80) = 0.402, p = 0.526
- For the identity concept of mass conservation: x^2(df=1, N=80) = 0.000, p = 1.000

- For the compensation concept of mass conservation: x^2(df=1, N=80) = 0.440, p = 0.507
- For the reversibility concept of mass conservation: x^2(df=1, N=80) = 2.175, p = 0.140

Then the aggregated results of each child were analyzed. Each child was labeled as TC if the child answered correctly on all four tasks of each test, PC if the child answered correctly on at least one of the tasks of each test, and NC if the child provided no correct answers (Church & Goldin-Meadow, 1986). TC was assigned the value 2, PC was assigned the value 1, and NC was assigned the value 0. Table 3 demonstrates the assignment of labels and the values of each test case. In each cell there is the absolute number of labeled participants followed by the corresponding percentage of the total participants in each test.

Table 3. Conservation Tasks Aggregated Scores

Experimenter	Subject Status	Liquid Conservation (n=80)	Mass Conservation (n=80)
Robot	NC	5 (6.3%)	4 (5.0%)
	PC	52 (65.0%)	55 (68.8%)
	TC	23 (28.8%)	21 (26.3%)
Human	NC	8 (10.0%)	7 (8.8%)
	PC	58 (72.5%)	58 (72.5%)
	TC	14 (17.5%)	15 (18.8%)

A different representation of Table 3 is presented using bar charts for each test (liquid conservation, mass conservation) and experimenter (robot, human), in the following figures. Figure 7 depicts the robot experimenter's liquid conservation number of children in each group. Figure 8 depicts the robot experimenter's mass number of children in each group. Figure 9 depicts the human experimenter's liquid conservation number of children in each group. Figure 10 depicts the human experimenter's mass conservation number of children in each group. All four test cases follow the same trend in the distribution of results.

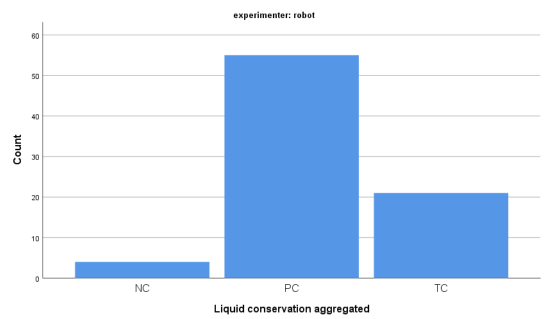

Figure 7. Robot Experimenter Liquid Conservation

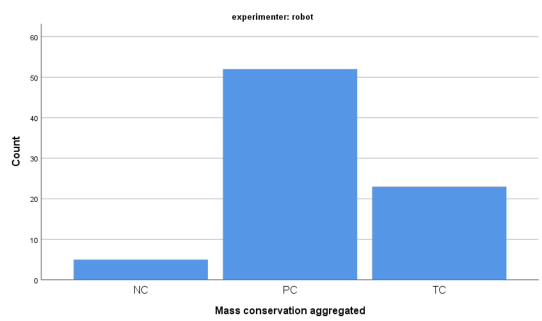

Figure 8. Robot Experimenter Mass Conservation

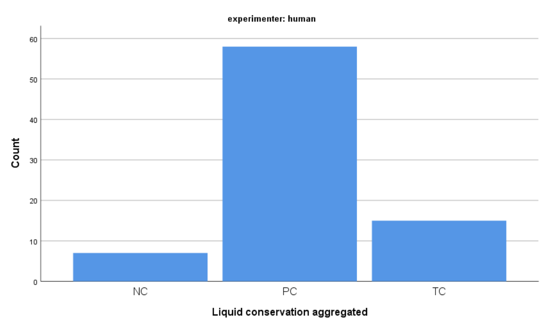

Figure 9. Human Experimenter Liquid Conservation

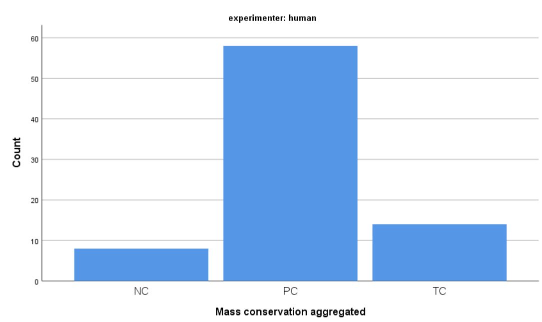

Figure 10. Human Experimenter Mass Conservation

The tests performed by the robot experimenter, either liquid or mass conservation, show better performance compared to the tests performed by the human experimenter. More specifically, liquid conservation tests PCs and TCs combined in the case of the robot experimenter were 75, whereas in the case of the human experimenter they were 72 (4.08% difference). Mass conservation tests PCs and TCs combined in the case of the robot experimenter were 76, whereas in the case of the human experimenter they were 73 (4.02% difference). An interesting observation is that the number of TCs in liquid conservation for the robot experimenter was 23 and for the human experimenter was 14 (48.64% difference), whereas in mass conservation for the robot experimenter it was 21 and for the human experimenter was 15 (33.33% difference). Unfortunately, the chi square tests of independence that were performed to check associations between the experimenters indicated no significant statistical differences. For the liquid conservation case the result was $x^2(df=1, N=80) = 1.898$, $p = 0.387$, and for the mass conservation case the result was $x^2(df=1, N=80) = 3.209$, $p = 0.201$.

Finally, Gamma coefficient was used to assess the association of the status (TC, PC, NC) of conservation awareness between liquid conservation and mass conservation labeled participants. Significant statistical association was found between them by having γ value of 0.693 and p value of 0.001 for the robot experimenter and γ value of 0.691 and p value of 0.002 for the human experimenter.

For tests performed by the robot experimenter:

- Out of 4 NCs in liquid conservation 2 were NCs and 2 were PCs in mass conservation.
- Out of 55 PCs in liquid conservation 3 were NCs, 40 were PCs, 12 were TCs in mass conservation.
- Out of 21 TCs in liquid conservation 10 were PCs, 11 were TCs in mass conservation.

For tests performed by the human experimenter:

- Out of 7 NCs in liquid conservation 2 were NCs, 4 were PCs, 1 was TC in mass conservation.
- Out of 58 PCs in liquid conservation 6 were NCs, 47 were PCs, 5 were TCs in mass conservation.
- Out of 15 TCs in liquid conservation 7 were PCs, 8 were TCs in mass conservation.

Thus, not only it is verified that the majority of children were PCs for that age group, but also that there was an association between the conservation tasks and knowledge transfer between them.

4. Discussion

The present study shows that the performance of children 5–6 years old, in Piaget’s conservation tests of liquid and mass, is enhanced for liquid conservation (4% more achieving at least partial conservation, while 48% more achieving total conservation) and for mass conservation (4% more achieving at least partial conservation, while 33% more achieving total conservation) when they are guided by a robot experimenter instead of a human one. Removing the human factor from the experimental process seems to improve the children’s awareness of the fact the liquid and mass quantities remained the same throughout all the tasks in general, despite the changes in appearance that occurred. Nowadays children are highly familiarized with technology, hence robots and tablets feel natural to them, and they need very little time to adjust. Humanoid-social robots offer multiple advantages to children and have been the subject of extensive research (e.g., Jamet et al., 2018). Children are motivated and they have a positive attitude and better concentration when they interface with a robot to perform tasks. Human experimenters can influence the answers of children (McGarrigle & Donaldson, 1974) because they act as authority figures and frequently, they put children in a stressful position of feeling that they are being judged. In contrast, robot experimenters are perceived as an equal interlocuter by children, making them feel calm and relaxed, thus performing at their best. We believe that the performance enhancement that occurred in the case of the robot experimenter in both tests was mostly owing to the aforementioned advantages.

Furthermore, it is important to note that comparing the percentage of complete conservers, partial conservers, and non-conservers, we discovered that the vast majority of children understood the conservation concepts. Most of them were classified as partial conservers, which validates our original hypothesis. Also, it is expected for that age group because it is near the end of the preoperational stage of Piaget’s phases of cognitive development. A crucial role, for having such positive results in the test, was played by the fact that children were required to answer correctly in four out of five introductory questions to ensure their understanding of basic concepts before they were eligible for participation in the study. This prerequisite definitely improved the percentage of correct results because children who were a little late in cognitive development and failed to answer the introductory questions were filtered out completely. This filtering was necessary because one of our main objectives was to examine the associations between the concepts of conservation for that developmentally marginal age group, and having subjects who could not answer any answers correctly would not provide any added value. To determine the exact age that conservation awareness occurs was out of scope of the current research.

Finally, the correct answers' percentages, in all cases (robot-liquid, robot-mass, human-liquid, human-mass), in the general concept of conservation were lower compared to the correct answers' percentages in all three specific concepts, identity, compensation, and reversibility. This is in line with the Piagetian theory that the specific concepts are prerequisites for children to achieve the general concept of conservation (Hooper, 1969). Unfortunately, except for the general trend of better performance in the specific concepts, significant associations between them and the general concept of conservation could not be established in this study because the statistical analysis of the results of the pairs (general-identity, general-compensation, general-reversibility) did not verify them. Previous research has indicated that conservation awareness can occur at earlier ages (e.g., McGarrigle & Donaldson, 1974) than initially thought by Piaget, and our results verified those claims. Though, it is possible that by experimenting on an older age group (e.g., 6–7+ years old), that is supposed to have acquired understanding of the conservation concepts more than younger ages, might provide more clear and significant associations between the general concept on the one hand and identity, compensation, and reversibility concepts on the other. Implications of the importance of the role of technology represented in this research by the robot-experimenter are evident in the fields of psychology and education and would be an interesting topic for further continuation of our research because, by keeping the experimental design and procedure the same, we can gain more insight on what is happening as a transitive state between the two age groups and Piaget's cognitive stages, preoperational and concrete operational.

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