Guide to build YOLO, a creativity-stimulating robot for children

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ABSTRACT

YOLO is a non-anthropomorphic social robot designed to stimulate creativity in children. This robot was envisioned to be used by children during free-play where they use the robot as a character for the stories they create. During play, YOLO makes use of creativity techniques that promote the creation of new story-lines. Therefore, the robot serves as a tool that has the potential to stimulate creativity in children during the interaction. Particularly, YOLO can stimulate divergent and convergent thinking for story creations. Additionally, YOLO can have different personalities, providing it with socially intelligent and engaging behaviors. This work provides open-source and open-access of YOLO's hardware. The design of the robot was guided by psychological theories and models on creativity, design research including user-centered design practices with children, and informed by expert working in the field of creativity. Specifically, we relied on established theories of personality to inform the social behavior of the robot, and on theories of creativity to design creativity stimulating behaviors. Our design decisions were then based on design fieldwork with children. The end product is a robot that communicates using non-verbal expressive modalities (lights and movements) equipped with sensors that detect the playful behaviors of children. YOLO has the potential to be used as a research tool for academic studies, and as a toy for the community to engage in personal fabrication. The overall benefit of this proposed hardware is that it is open-source, less expensive than existing ones, and one that children can build by themselves under expert supervision.
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Specifications table.

Hardware name	YOLO – Your Own Living Object
Subject area	Educational Tools and Open Source Alternatives to Existing Infrastructure
Hardware type	Other: Creativity Support Tools
Open source license	CC-By Attribution 4.0 International
Cost of hardware	$150–200
Source file repository	https://osf.io/kwrft/

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1. YOLO – Your Own Living Object

Children are avid explorers, using objects to play while learning about how the world works. [59,84,75]. In particular, the usage of toys during play have shown to be related to healthy cognitive development [73]. A new generation of technological objects is joining the more traditional set of toys, including smart-phones, tablets, virtual and augmented reality devices, and social robots. The emergence of technologies for children led to changes in play-time, deviating from traditional sand-boxes and parks to digital and interactive devices. Research shows that children are willing to use and interact with technology [8,44,62] and that technology can have positive benefits in children's learning [33] and creative levels [61]. Additionally, technology has been driving developed societies towards more "creative economies" where the value of innovation, problem-solving, and collaboration, is favored over standardized knowledge acquisition and repetitive tasks [24,60,45,17].

In our work, we aim to contribute to the development of a social robot that will benefit children's creativity during playtime. Children play with this robot while still maintaining traditional play landmarks, such as physical, free, and outdoor play. The specific use-case scenario consists of a storytelling activity in which children use the robot as a character for their stories. It is in the *interaction* with the robot that creativity is intended to be stimulated, similarly to what was developed with other toys [77,83]. This makes YOLO part of a new generation of technological toys that has the potential to boost creative abilities. During the process of play, the robot provides stimuli for children to develop new story-lines for the stories they create. The robot does so by using techniques of creativity training [3]. Particularly, it stimulates two core elements of the creative thought: divergent and convergent thinking [26,22,50], two modes of creative thinking that usually are naturally stimulated through play [39]. This robot is called YOLO, short for Your Own Living Object (see Figs. 1 and 2).

2. Related work

In this section, we contextualize the development of YOLO within the general field of Human-Robot Interaction (HRI) and Child-Robot Interaction (cHRI). We frame our design decisions based on design research including user-centered design techniques, and theories about child development, personality, and creativity.

2.1. Human-robot interaction

HRI is a field of research dedicated to the design and evaluation of robotic systems that interact with humans [30]. These robots have been designed with the ability to "communicate and interact with us, understand and even relate to us, in a personal way" [15]. They have been designed with different embodiments, using a rich taxonomy of expressive behaviors [27], classified according to the environment in which they operate, and to the intended application field [10]. Additionally, their interaction modalities range from emotional expression [55] (including empathy [54], body gestures [69,70], and expressive lights [7]) to color, motion, and sound [40]. High successful interactions with humans tend to occur when the interactive and expressive modalities of robots match their physical embodiment [48]. A robot's embodiment can also range from a human-like appearance [36,43] to non-humanlike shapes [16,85,19]. When a mismatch is perceived between the physical appearance of a human-like robot and its behavior, feelings of eeriness and revulsion may arise, denoting the so-called Uncanny Valley Effect that robot designers want to avoid [48]. To counter this effect, we chose to develop a non-anthropomorphic robot using non-verbal elements, such as colors and movement, to communicate with children.

Fig. 1. Perspective views of YOLO from left to right: top, top-side, side, bottom-side, and bottom.
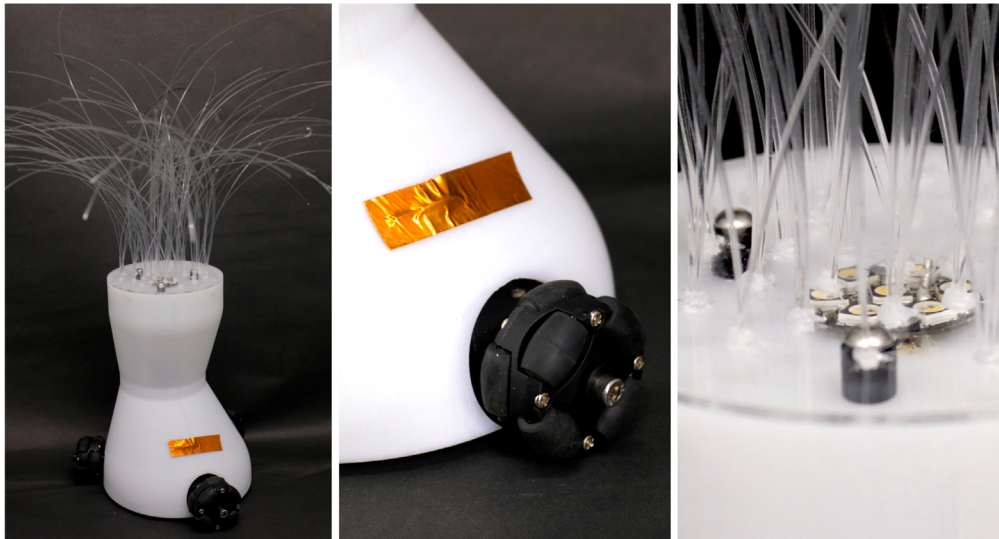
Fig. 2. Detailed views on YOLO robot.

2.2. Child-robot interaction

Our work focuses on playful robotic technology dedicated to children. A wide range of research about technologies for children, especially social robots, has been developed, with associated benefits for education [9] and social play [79,18]. When robots are skillfully used by the teachers and aligned with the students' educational needs [11], such benefits include positive achievements, as an increase in motivation for learning and improvement in collaborative learning [76]. Another major benefit concerns the support of multiple paces and learning styles through play [80], specifically when robots are applied to foster creative thinking and creative expression [63]. The combination of play and learning denotes the potential of robots in making scientific domains of knowledge – such as maths and geometry – approachable for children [64]. This notion aligns with the culture of Digital Manipulatives, for which computers and robots are used as tools to learn about a variety of school topics. Successful examples of social robots that engage children and increase learning acquisitions are the LOGO Turtle [56,57], Curlybot [28], KIBO [25], and Shybo [42]. These novel learning formats have been supported by emerging theoretical frameworks, such as the Digital Play Framework, that intend to guide future design directions about technological objects for children [13].

Social robots bring new opportunities for designers to rethink areas of change concerned with how children relate, learn, and play [1]. However, most robots developed for children are off-the-shelf robotic platforms (such as SoftBank Robotics' NAO and Pepper, or MyKeepon by BeatBots), oftentimes constrained in their expressiveness given the task at hand. In our work, we have designed and fabricated a social robot including children at all design stages [3], to ensure its specificity for creativity stimulation during play.

2.3. Play, create, develop

Creativity is recognized as one of the most sought-after abilities [23]. The economy of developed societies is changing, taking the prospect of a creative economy rather than following with the old industrial economy mindset. The standardized knowledge that before was valued is now being replaced by creative and innovative values [65]. However, in contrast with this change, a decline in creative abilities during the middle childhood years seem to occur, a phenomenon called "creative crisis" [37]. Research has shown that everyone has the potential to be creative, as creativity is a skill that can be developed if nurtured [71]. With our work, we aim to develop a new technological toy to stimulate children's creativity.

According to Piaget's Stages of Development, during middle school age-years, children are in the Concrete Operational Stage, characterized by logic and operational thinking, being able to reason about objects and the relations among them, but having difficulty entertaining hypothetical statements or propositions [58]. Toys are important during the Concrete Operational Stage since the manipulation of objects has the potential to foster children's development and growth [51]. Play is a core activity in children's lives, where objects are manipulated and meanings are explored (e.g., during imaginary play in which a stick can be imagined as a horse) [58,84,51], being the leading source of growth [84] and learning [38,47]. Playful activities are a way to stimulate creativity by fostering the development of cognitive and affective processes [67] that enable formal thinkers to structure solutions for complex challenges [52]. In fact, if creativity is stimulated during play in childhood, it has the potential to be developed into mature creativity in adulthood [6,68]. Pretend play, in particular, is associated with divergent thinking, a major indicator of creativity [73].

2.4. Robot design

YOLO was designed using formative research and feasibility studies. Formative research consists of an exploratory research methodology whose goal is to guide a design process, allowing ongoing intermediate assessments [29]. By identifying and solving concrete usability problems throughout the entire process design, current systems can be improved or new ones are developed [81,82]. Feasibility studies consist of are pieces of research performed before the main study, used to estimate crucial parameters that are needed to design the main study [4]. These intermediary studies which will help to prepare for full-scale and large research intervention, allowing for low-cost improvements before experimentally testing the effectiveness of an interventions or product [14]. Additionally, we followed the Double-Diamond Design Process Model to design YOLO, an established theory in the field of design research [21,53].

Contextual design was used by involving children at different design stages of the robot [3]. The importance of contextual design lies in the fact that it validates the already embodied system where the robot will exist in, capturing the child's world as the floor for design decisions [32,31]. Data gathered during fieldwork was the base criterion for deciding what needs to be addressed, what the robot should do, and how it should be structured within the reality of children [12]. Additionally, we took into account the Big Five Model of Personality to inform the design of the social behaviors for the robot [20]. Finally, the robot was aimed to stimulate creativity during play. Therefore, the creativity-stimulating behavior of YOLO was based on two established creativity techniques for idea generation, an important stage in story creation. These techniques are called "contrast" and "mirror" [74]. While the Contrast technique stimulates divergent thinking, the Mirror technique is responsible for the development of convergent thinking. Both modes of thinking are required to establish the emergence of creativity [41]. Therefore, YOLO's behavior is not only loaded with social behaviors (derived from personality theories) but also with behaviors that can lead to creativity stimulation in children.

3. Interaction elements

To sustain playful and creative interactions with children, YOLO makes use of implicit interaction modalities, such as movements and lights, to communicate with children [35]. YOLO's interactive elements are described below.

3.1. Lights and movement as interaction modalities

Lights and movement were chosen as the main interaction modalities between the robot and children as this combination was recognized as one of the most efficient nonverbal multi-modal communication for non-anthropomorphic robots [40]. YOLO interacts with children by making use of lights that display different colors creating different emotional expressions by using different scales of brightness levels that create a so-called "blinking behavior". For example, when the robot exhibits an introvert personality, it would use less light-blinking behaviors with smooth transitions between them; when exhibiting an extrovert personality the light-blinking behavior would happen with more frequency and at faster speeds of transition. Additionally, movement is used for interaction with YOLO performing different navigation patterns at varying speeds. In this sense, the robot senses how children move it (the robot can recognize the manipulation patterns of children while grabbing it), and reacts to these behaviors. For example, if children perform angular movements patterns with the robot (pretending, e.g., that the robot is avoiding obstacles, similarly to what children do when they play with car toys), the robot detects these and can react to them either by imitating them or by doing a different movement. In this case, the robot is reacting to a movement previously performed by children, in what we called a *reactive behavior*. On the other hand, the robot can initiate an autonomous behavior to stimulate new ideas during play time, in what we called *proactive behavior*, which means that the robot, without being previously manipulated by children, can start moving around to call their attention for playing.

3.2. Abstract shape as imagination trigger

YOLO has a minimal abstract body shape as an invitation to children's imagination. Literature states that conceiving states of fantasy in which reality constraints have been dropped serve as a technique to increase idea generation [74]. Therefore, by designing an embodiment that does not resemble previously known objects, YOLO can serve as any character that children wish for their stories, increasing idea generation (which is part of the divergent thinking in creative thought). The abstractness of the robot is envisioned to amplify imagination possibilities for children's stories, inciting them into creating a wide range of story-lines that contribute to their creative thinking.

3.3. Touch for shared control

Children are usually in full control of their toys. However, this is not the case when they interact with autonomous robots, as interactive technology performs actions that are not controllable by children due to their autonomous nature. During an interaction, this can lead to positive effects, such as engagement due to novelty, but can also create frustration and sometimes even fear in children, possibly leading to interaction breakdowns with robots [72]. To address this aspect, YOLO has a shared control option that gives control over the interaction back control to children, similarly to what occurs during

interactions with their traditional toys. This was made possible by using capacitive touch sensors in the robot's shell. When children touch the robot, the capacitive touch sensor is activated and the robot refrains from performing any autonomous behavior. During this deactivated time, children can play with it as they do with traditional toys. When children release the robot, which means that the capacitive sensor does not recognize touch, the robot returns to its fully autonomous mode. This shared control enables children to have the control they are used to with their traditional toys at certain levels of the interaction, and at the same time enables the robot to perform autonomously.

4. Technical elements

In this section, we detail YOLO's technical elements related to its hardware design.

4.1. Small-scale and light-weight design

YOLO is a 167 × 120 mm robot with three omni-wheels that enable navigation and manipulation in any direction (see Fig. 3). It was designed to be a small-scale and light-weight robot meant for children's hands' size and easy manipulation. With most robots, the space required by electronic circuits, wires, and power, make small-size and light-weight designs hard to achieve. In fact, most off-the-shelf robots for children are heavy to hold, e.g., the NAO robot weights 5.4 kg. In its final version, YOLO has a weight of approximately 0.5 kg, the equivalent of a basketball, and its half-hourglass shape enables an easy grabbing for children's hand size (see Figs. 2 and 3).

4.2. Child-proof design

YOLO's shell was fabricated using 3D printing material, with options for laser cutting. The robot's interior components (such as screws and standoffs) are made of nylon to avoid shorts between electrical boards. The circuitry and electronic boards were assembled in a compact and robust layered design in order to be safely manipulated by children (see Fig. 4). These materials and assembly processes make YOLO child-proof, accommodating for unrestricted and uncertain manipulations of the robot during play.

4.3. Grab-and-go play

YOLO was designed as a standalone and portable robot for a playful grab-and-go mindset. To enable portability, the robot has a robust internal power system, providing energy to all internal components. Compact power designs for robots are hard to achieve due to the large size of commercially-available batteries, commonly presenting non-ergonomic shapes. In fact, most robots for children are mostly stationary and dependent on power outlets to function, e.g., MyKeepon is a small and light weighted robot for children, however, it is a power outlet dependent robot. YOLO's portability enables free play both indoors and outdoors, not constraining it to pre-determined spaces. This is similar to what happens when children play with their traditional toys.

5. Design files

YOLO can be build using the design files included in Table 1 and represented in Fig. 5. The design files are in STL format and ready to be 3D printed. Some of these files can be converted to a DXF format, adding a laser cutting option for faster and cheaper opportunities to fabricate YOLO. If opting to laser cut some of the components, note that the thickness of the laser
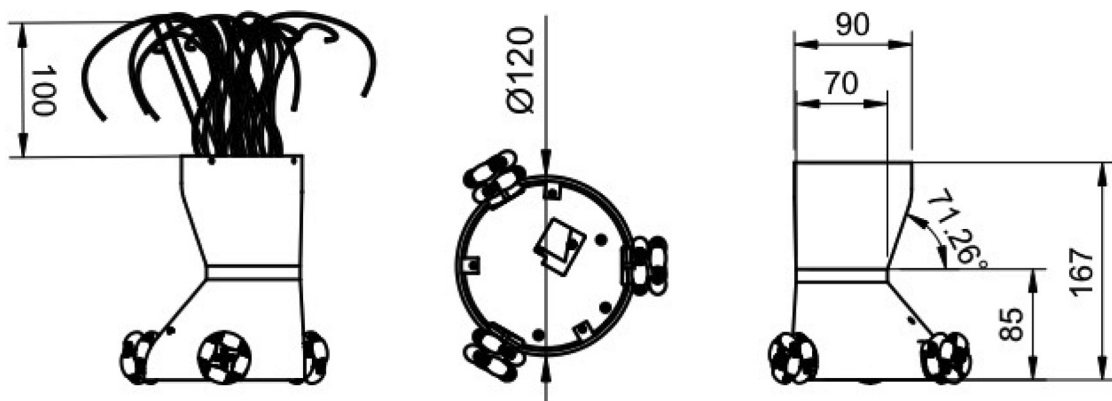

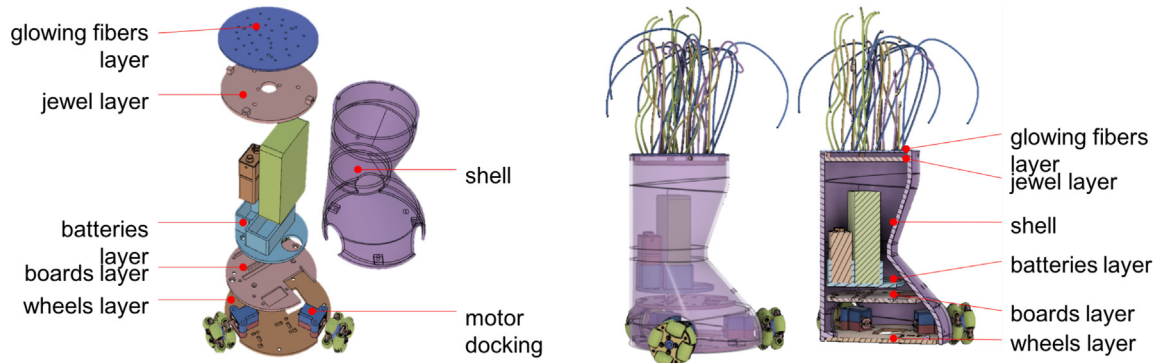**Fig. 3.** YOLO's drawing with main dimensions in mm.

Fig. 4. YOLO's exploded view (on the left) and section analysis with component coloring (on the right).

Table 1
Design files to build YOLO.

Design file name	File type	License	Location of the file
Shell	CAD file in STL format	CC BY 4.0	https://osf.io/xdgf5/
Batteries layer	CAD file in STL format	CC BY 4.0	https://osf.io/3dgyb/
Boards layer	CAD file in STL format	CC BY 4.0	https://osf.io/4gj65/
Wheels layer	CAD file in STL format	CC BY 4.0	https://osf.io/hyb56/
Glowing fibers layer	CAD file in STL format	CC BY 4.0	https://osf.io/bqg4f/
Washer	CAD file in STL format	CC BY 4.0	https://osf.io/5pdwj/
Motor docking (1)	CAD file in STL format	CC BY 4.0	https://osf.io/crz7j/
Motor docking (2)	CAD file in STL format	CC BY 4.0	https://osf.io/eruac/
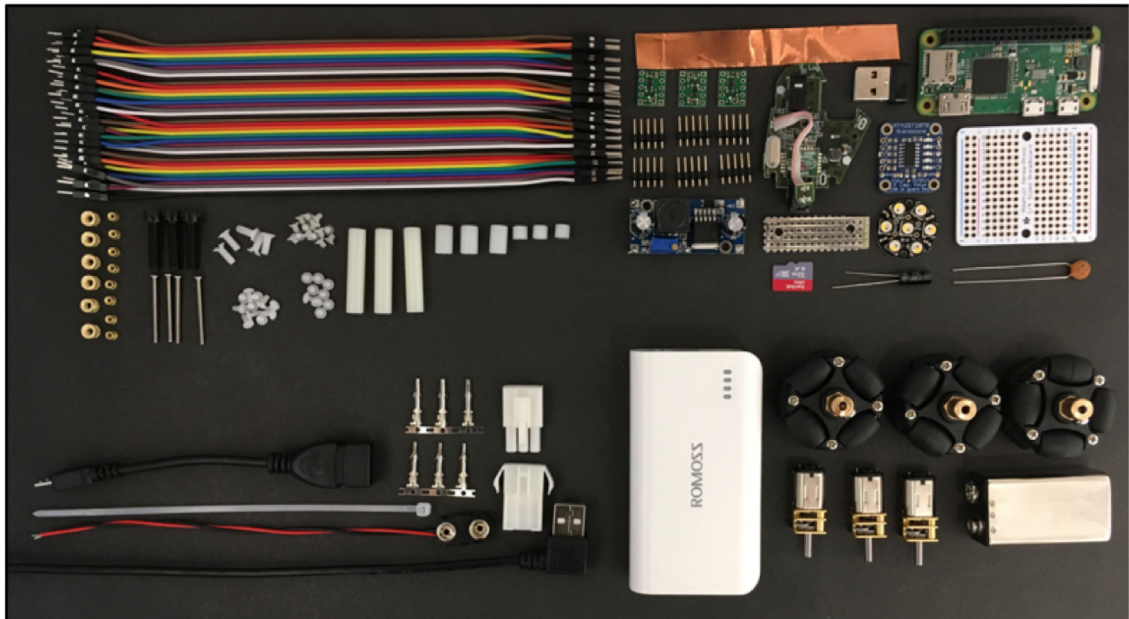
Fig. 5. YOLO parts lineup.

cutting material should correspond to the CAD model dimensions. We suggest choosing a material for the laser cutter work that protects electronic boards, such as acrylic. Below is the summary of the design files presented in Table 1:

- **Shell** – File with the cover of the robot. This is the largest 3D printing file and requires a 3D printer capable of operating at large dimensions – at least $120 \times 200 \times 200$ mm of printing capability. Consider a vertical bottom-up position for printing the shell. Support material should be added on the faces of the three tabs. This design file does not present a laser cutting option as it is made of 3D organic shapes not ideal for laser cutting work.

- **Batteries**, *boards*, and *wheels layers* – These design files are composed of three circular platforms that should be placed on the interior of the shell to hold all the electronic components in place (see Fig. 4). Consider printing the layers horizontally. Support material is needed only on the face of the counter-bore holes of the larger platform. The laser cutting option is valid for this design file.
- **Jewel layer** – This file contains the design that serves to nest the LED jewel that will be attached from the top of the shell (see Fig. 4). Consider printing the LED nest horizontally with support material. This file does not support a laser cutting option due to its 3D design requirement.
- **Glowing fibers layer** – This design file contains the plate where the optical fibers should be glued (see Fig. 4). Consider printing the LED nest horizontally with support material. The laser cutting option is valid for this design file.
- **Washer** – Washers should be placed between the "Jewel layer" and the "glowing fibers layer" to secure this connection (see Fig. 4). YOLO uses three washers to support this connection, so consider printing 3 parts. The laser cutting option is valid for this design file.
- **Motor docking (1) and (2)** – Composed of two files that together provide docking for the motors. Support material is not needed for 3D printing. The laser cutting option is valid for "Motor docking (2)".

6. Bill of materials

The total estimated expenses for building YOLO is of approximately $200. Although this cost might strike as expensive for a home-made robot, the total estimate price includes purchases of items that come in large packs, such as battery clips and wire zip ties, or that come with extra material quantities, as wires and screws. A concrete example is the battery clips that come in packs of 10, while YOLO requires only 1; wires have an extension of 25ft and YOLO requires short extensions due to its compact design. Therefore, the total estimated price can be reduced if YOLO is built in a laboratory or a maker space that already has some of the tools and materials for building and assembling. A description of the total bill of materials is presented in Tables 2–5.

7. Assembly

Instructions for the robot's assembly are provided below.

7.1. Assembly preparation

The assembly requires the following tools: hacksaw, utility knife, screwdriver set, calipers, scissors, soldering kit (including solder spool, soldering station, wire stripper, diagonal cutters, solder wick for solder removal, soldering vise with a magnifying glass, and a panavise), and glue. 3D print and laser cut the required materials in Table 2 and have ready the components in Tables 3–5 and Fig. 5. Before assembly, configure the voltage transformer with an input of 5.0 V and step down the buck converter output for 1.5 V. Additionally, follow the steps described below:

1. **Hack mouse sensor**
   (a) Hack a mouse sensor that will serve as in-built system for motion detection of the robot.

Table 2
Bill of electronic components of YOLO.

#x270E;	Designator	Component	Quantity	Cost per unit in USD	Total cost in USD	Supplier
1	Raspberry Pi	Raspberry-pi w zero	1	10.00	10.00	Adafruit
2	Touch sensor	Standalone 5-pad capacitive touch sensor breakout AT42QT1070	1	7.50	7.50	Adafruit
3	Jewel	NeoPixel jewel 7 × 5050 RGBW LED w/ integrated drivers natural white ∼4500 K	1	6.95	6.95	Adafruit
4	Voltage converter	LM2596 DC-DC buck converter step down module power supply output 1.23 V–30 V	1	14.95	14.95	Amazon
5	Optical sensor	Logitech wireless mouse M170	1	9.00	9.00	Amazon
6	Motor driver	DRV8838 single brushed DC motor driver	3	2.99	8.97	Pololu
7	Motor	Micro metal gearmotor HP 6 V	3	15.95	47.85	Pololu
8	Protoboard	Adafruit perma-proto quarter-sized breadboard PCB	1	2.50	2.50	Adafruit
9	Power distribution board	Universal glass fiber PCB board	1	3.80	3.80	DX
10	Ceramic capacitor	Ceramic capacitor disc 0.047 µF 25 V +80% to −20%	1	0.25	0.25	Jameco Electronics
11	Electrolytic capacitor	10 µF 50 V electrolytic capacitors	1	1.95	1.95	Adafruit

Table 3
Bill of power and connection components of YOLO.

#x270E;	Designator	Component	Quantity	Cost per unit in USD	Total cost in USD	Supplier
12	Wires	Hook-up wire spool set 22AWG solid core 6 × 25 ft	1	15.95	15.95	Adafruit
13	Omni wheels	38 mm by 3 mm omni wheels	3	6.40	19.20	Aliexpress
14	Power bank	USB battery pack 4000 mAh, 5 V, 1A	1	24.95	24.95	Adafruit
15	9 V battery	EBL advanced 9 V 1200 mAh lithium batteries	1	5.50	5.50	Amazon
16	SD card	SanDisk ultra 32 GB micro SDHC UHS-I card with adapter	1	12.96	12.96	Amazon
17	Router	TP-Link N300 wireless wi-fi router 2 × 5dBi high power antennas up rightarrow 300Mbps	1	19.99	19.99	Amazon
18	Glowing fibers	CHINLY roll PMMA plastic	1	8.44	8.44	Amazon
19	Copper tape	Copper foil tape with conductive adhesive	1	5.95	5.95	Adafruit
20	Battery clip	Cable connection 9 V plastic battery clip connector buckle	1	0.40	0.40	Amazon
21	Female USB to micro USB	USB A female to micro USB B 5 pin male adapter cable	1	2.50	2.50	Amazon
22	Micro USB	Micro USB plug rightarrow 5.5/2.1 mm DC barrel jack adapter	1	1.95	1.95	Adafruit
23	90° USB	USB to right angle mini USB with 90°	1	6.99	6.99	Amazon

Table 4
Bill of fasteners for YOLO.

#x270E;	Designator	Component	Quantity	Cost per unit in USD	Total cost in USD	Supplier
24	M2 brass inserts	Heat-set inserts for plastics; M2 × 0.4 mm thread; 2.9 mm length	28	0.10	10.44	McMaster
25	M3 brass inserts	Heat-set inserts for plastics; M3 × 0.5 mm thread; 3.8 mm length	3	0.12	12.30	McMaster
26	Hex standoff	Nylon 6/6 plastic hex standoff 3/16″; 3/16″ long; 2–56 female thread	2	1.47	2.94	McMaster
27	Small round standoff	Nylon 6/6 female threaded round standoff 1/4″ OD; 13/32″ length; 4–40 thread	2	1.40	2.80	McMaster
28	Big round standoff	Nylon 6/6 female threaded round standoff1/4″ OD; 1–1/4″ length; 4 − 40 thread	3	2.00	6.00	McMaster
29	M2 pan head screw	Nylon pan head phillips screws M2 × 0.40 mm thread 5 mm	18	0.90	4.98	McMaster
30	M3 pan head screw	Nylon pan head phillips screws M3 × 0.50 mm thread 16 mm	3	0.23	7.82	McMaster
31	Long screw	Passivated 18–8 stainless steel pan head phillips screw 1–72 thread 1″ long	6	1.33	11.09	McMaster
32	Socket head screw	Black-oxide alloy steel socket head screw M4 × 0.7 mm thread 18 mm long	3	0.34	11.31	McMaster
33	Small flat head screw	Nylon slotted flat head screws; 100° countersink; 2–56 thread; 1/8″ long	4	0.25	6.13	McMaster
34	Big flat head screw	Nylon slotted flat head screws 100° countersink; 4–40 thread; 5/16″ long	13	0.73	5.59	McMaster

Table 5
Bill of structural components of YOLO.

#x270E;	Designator	Component	Quantity	Cost per unit in USD	Total cost in USD	Supplier
35	Shell	3D printed design in PLA	1	19.28	19.28	FF3DM
36	Circular layers	3D printed design in PLA	1	68.44	68.44	FF3DM
37	Motor docking	3D printed design in PLA	6	2.00	12.00	FF3DM
38	Washer	3D printed design in PLA	3	1.00	3.00	FF3DM
39	Glowing fibers layer	Laser cut design in clear acrylic with 1.50 mm of material thickness	1	13.54	13.54	Sculteo

    (b) Tutorial video on how to hack a mouse:https://youtu.be/Jz-cXqAwu4o
2. **Place brass inserts**
    (a) Place the brass inserts in the dedicated places using a soldering iron (Fig. 7, steps 1–3).
    (b) Tutorial video on heating brass inserts:https://youtu.be/HB2Q_Wywl1s
3. **Cut circboard**
    (a) Cut a circboard and drill two 2.10 clearance holes for attachment.
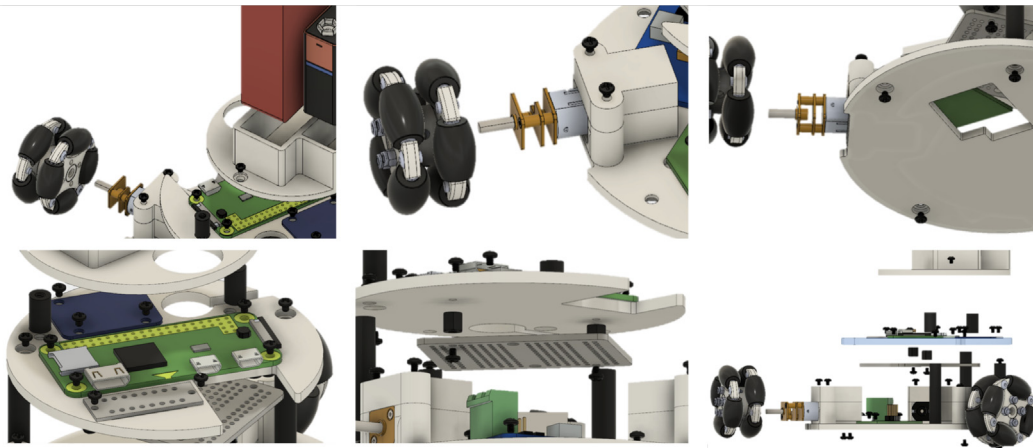
Fig. 6. Close-ups on YOLO's inside.

   (b) Tutorial video for cutting a circboard: https://youtu.be/ummbqeoAhJY
4. **Cut glowing fibers**
   (a) Cut the glowing fibers and attach them to the glowing fibers layer by using a hot glue gun or other effective glue. The length of the glowing fibers size can be selected by personal preference. We used lengths between 140 and 170 mm.
   (b) Tutorial video on cutting glowing fibers:https://youtu.be/7TzWtuXsoN8

When these steps are finalized, start the assembly flow of YOLO described in Section 7.2.

7.2. Assembly flow

A step-by-step assembly flow with an action Diagram [2] is present in Fig. 7. Follow each step and complement the assembly flow with the wiring instructions on Fig. 8. An exploded view of YOLO that supports the understanding of the final robot configuration is present in Fig. 4, with close-up views on Fig. 6. When the robot is fully assembled, attach a batch of copper tape to the shell of the robot to connect the wire that comes from the capacitive touch sensor. This will enable the robot to respond to touch.
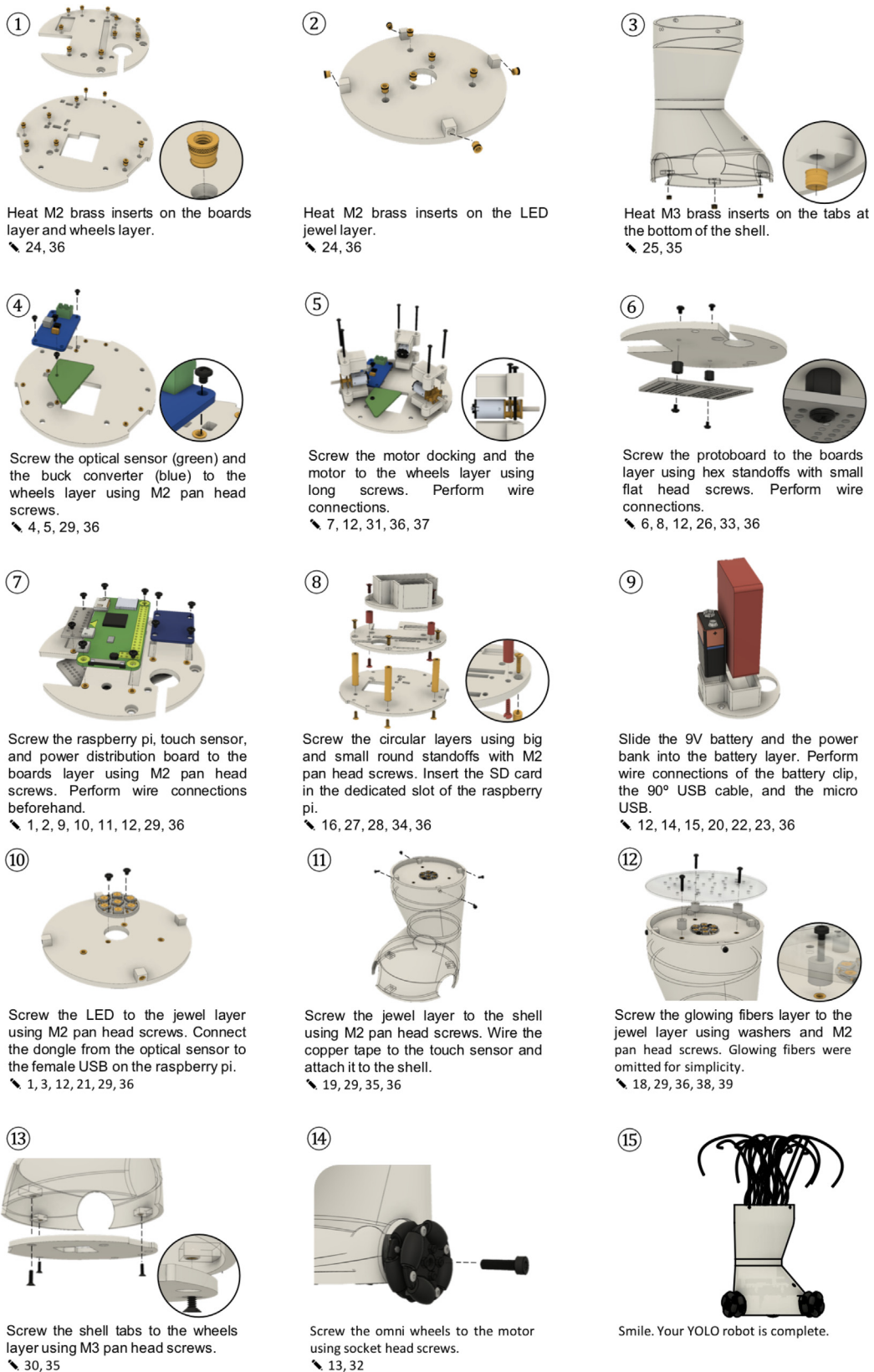
7.3. Assembly safeguards

Assembling YOLO is a process that involves interacting with mechanical tools and machinery for which safety guards are required. To the best of our knowledge, no safety guidelines for personal fabrication have been formally established, and mis-uses have been considered users' responsibility [49]. As such, we strongly advise YOLO makers to follow our recommended safeguards.

It is advisable to assemble the robot under expert adult supervision at all times. Additionally, assembling this robot requires knowledge over some mechanical engineering procedures, such as soldering. We recommend a tutorial about soldering by Mitch Altman, Andie Nordgren, and Jeff Keyzer, "Soldering is Easy". We advise to train the art of soldering using a training board, and only after mastering this art, start soldering YOLO. The physical presence of an expert person during soldering, wiring, and 3D printing or laser cutting is recommended.

8. Operation instructions

To operate YOLO, consider the schematics present in 9. YOLO can display different social behaviors. Therefore, it can be used as a creativity-stimulating robot for children's playtime (for this, consider downloading an available version of the software with pre-sets that we have developed available at this link. In this case, YOLO will be interacting with children in a playful way, while seeking to stimulate their creativity. Another way is to develop a software to operate YOLO. This can be performed by any person with some knowledge of programming. In this case, YOLO's software can be developed and personalized according to the needs and goals of the developers. To develop software for YOLO consider a Python script-based language and Raspberry-Pi's specifications and the API created and available at this link : https://github.com/patricialveso-liveira/YOLO-Software.

To start operating YOLO, combine the materials required to initialize the robot present in Table 6 with the operating instructions in Fig. 9. It is important to note that the performance of the robot is dependent on battery life, router range, and strong wiring connections. Regarding the battery, the average life is between 5 and 7 h. This average can fluctuate depending on the playing behavior of children, i.e., if children interact more with YOLO, the battery life will decrease as

① Heat M2 brass inserts on the boards layer and wheels layer.
✎ 24, 36

② Heat M2 brass inserts on the LED jewel layer.
✎ 24, 36

③ Heat M3 brass inserts on the tabs at the bottom of the shell.
✎ 25, 35

④ Screw the optical sensor (green) and the buck converter (blue) to the wheels layer using M2 pan head screws.
✎ 4, 5, 29, 36

⑤ Screw the motor docking and the motor to the wheels layer using long screws. Perform wire connections.
✎ 7, 12, 31, 36, 37

⑥ Screw the protoboard to the boards layer using hex standoffs with small flat head screws. Perform wire connections.
✎ 6, 8, 12, 26, 33, 36

⑦ Screw the raspberry pi, touch sensor, and power distribution board to the boards layer using M2 pan head screws. Perform wire connections beforehand.
✎ 1, 2, 9, 10, 11, 12, 29, 36

⑧ Screw the circular layers using big and small round standoffs with M2 pan head screws. Insert the SD card in the dedicated slot of the raspberry pi.
✎ 16, 27, 28, 34, 36

⑨ Slide the 9V battery and the power bank into the battery layer. Perform wire connections of the battery clip, the 90° USB cable, and the micro USB.
✎ 12, 14, 15, 20, 22, 23, 36

⑩ Screw the LED to the jewel layer using M2 pan head screws. Connect the dongle from the optical sensor to the female USB on the raspberry pi.
✎ 1, 3, 12, 21, 29, 36

⑪ Screw the jewel layer to the shell using M2 pan head screws. Wire the copper tape to the touch sensor and attach it to the shell.
✎ 19, 29, 35, 36

⑫ Screw the glowing fibers layer to the jewel layer using washers and M2 pan head screws. Glowing fibers were omitted for simplicity.
✎ 18, 29, 36, 38, 39

⑬ Screw the shell tabs to the wheels layer using M3 pan head screws.
✎ 30, 35

⑭ Screw the omni wheels to the motor using socket head screws.
✎ 13, 32

⑮ Smile. Your YOLO robot is complete.

Fig. 7. YOLO's assembly flow. Numbering accompanied by the symbol ✎ correspond to materials on Tables 2–5.
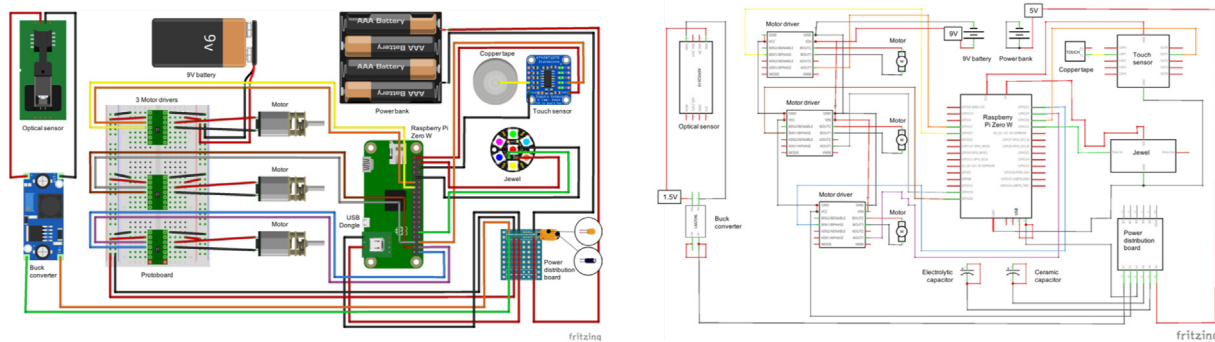
Fig. 8. Wiring schematics of YOLO with visual components (on the left) and circuit schema (on the right).

the robot is prompt to perform more behaviors. If one or more omni-wheels start to not move, substitute the 9 V battery, as there might be a power shortage. For full performance, YOLO's batteries need to be properly charged. Therefore, if the robot is non-responsive, recharge the power bank and try again when it is full. If YOLO continues non-responsive, check the wiring connections as they might need extra soldering as the unrestricted movements during children's play can weaken the connections. As the router range is wide, children can play with YOLO both indoors and outdoors. If YOLO starts being non-responsive, consider a smaller distance between the robot and the router.

Operation safeguards

YOLO is a robot made for children. Due to its target group and playful application nature, there are no major hazards when operating and playing with it. However, like any other technological toy, children should be supervised by an adult at all times. Additionally, a responsible adult should be in charge of initializing YOLO.

9. Validation and characterization

The field of HRI is characterized by multidisciplinarity, for which the open access to research tools, such as robots' hardware and software, is crucial [34]. YOLO presents as a low-purchase and low-maintenance cost robot, that can be used as a tool for research studies with children. The open source hardware of YOLO thus provides opportunities for researchers with and without engineering background to build this robot and further use it targeting their own research goals, without depending upon complex robotic platforms. To demonstrate how this robot can be applied to academia, researchers can use it as a platform to explore the design of behaviors for a robot aimed at interacting with children. Another example is the usage of this robot by the social and cognitive sciences field as a controllable and programmable tool, to study the developmental aspects of children when interacting with robots. Predominantly, the scientific community relies on the usage of off-the-shelf robots as their research platforms when performing studies. Nonetheless, off-the-shelf robotics platforms are generally expensive (with purchase prices ranging from $5.000 to $20.000, or more) and associated with high maintenance costs. In addition, the majority of these robots require special transportation services to be used during field studies, due to their robust size and heavyweight, placing additional costs for academic laboratories. YOLO offers a less expensive yet interesting solution for research.

In the scope of this work, we have used YOLO as a research tool for STEAM activities aimed at promoting robotics knowledge among young children and adults. We have conducted two use-cases with YOLO in the scope of this work. In the first use-case, we performed live demos of YOLO with the robot operating autonomously at the Sciencenter, a science museum for children in Ithaca, NY, USA. During the time YOLO was in the museum, children approached the robot and were invited by the principal researcher to create stories with the robot. Children created short stories alone, together with other children, or with the help of their parents. To help guide the process of story creation, we provided the first story-line in which the robot "was asleep and dreaming" and asked children to tell the story of the robot's dream. Therefore, when children interacted with it, they started creating story-lines, such as "the robot is dreaming that it goes to school". These narrations would change according to the robot's behavior and to the will of children. The second use-case was to present YOLO at the RAW Exhibition organized by the Medium Design Collective, to showcase the process of creation of different technologies

Table 6
Materials and their usages required to initialize YOLO.

Material	Usage
YOLO robot	Artifact that will be operated.
Router	To connect the Raspberry Pi and to the software program via wi-fi.
Computer/laptop	To initialize YOLO's software program.
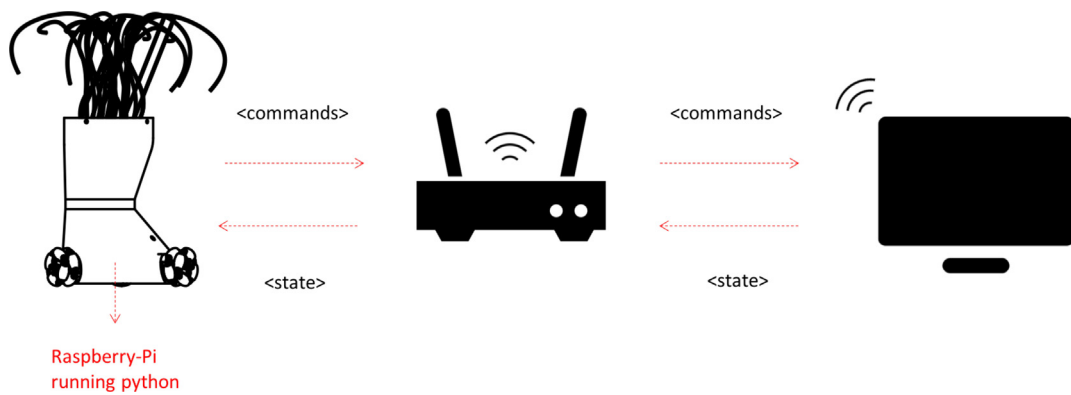
Fig. 9. Operating instructions for YOLO.

Fig. 10. YOLO exhibited in STEAM activities for children (on the left) and adults (on the right).

and art installations. In this case, we demonstrated the design process of this robot, from prototype to its final shape and behaviors. This enabled adults to engage in conversations about the robot's working and the design decisions made during its fabrication process. During these activities, YOLO interacted with more than 50 children and a hundred adults (see Fig. 10).

10. Conclusion

Open-access and open-source tools provide opportunities for lay people to engage in personal fabrication where knowledge is shared while building a robot or other technological device [78,66,46]. In this work, we provided a guide for building a social robot called YOLO, aimed at being a toy for children's playtimes. The open-access initiative is aligned with the strategic plan for the Open Educational Movement, whose goal is to provide equal access to knowledge and educational opportunities across the world, increasing the educational resources for children [5].

During the process of building YOLO concepts related to mechanical engineering such as soldering, performing wire connections, etc are learned. The acquired knowledge can be applied to other curricular domains, making YOLO an object to think-and-learn-with [56]. Additionally, the hands-on experience of building YOLO trains children's dexterity, an important ability acquired through physical play. YOLO can be used in a wide range of application contexts, such as in school and at home.

Declaration of interest

None.

Human rights

The work described has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans; informed consent was obtained for experimentation with human subjects. The privacy rights of human subjects were always considered.

Acknowledgements

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.ohx.2019.e00074.

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