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Use a robot to serve experimental psychology: some examples of methods with children and adults

O. Masson ^{*,1}, J. Baratgin ^{1,2}, F. Jamet ^{1,3}, F. Ruggieri ¹, D. Filatova ⁴

¹ CHArt, Université de Paris 8 and EPHE, France

² Institut J. Nicod, Paris, France

³ Université de Cergy-Pontoise, France

⁴ Institute of Pedagogy and Psychology, University of Jan Kochanowski, Kielce, Poland

*Corresponding author, olivier.masson@univ-paris8.fr

Abstract—Robots are increasingly used in scientific research. Given the multitude of existing robots, how to choose the most adapted robot to a research and above all, how to use it to study biases in reasoning or in decision making? We suggested studying well-known biases from a new point of view: social norms, including social behaviors, social context and pragmatics of language. How to measure the impact of implicit social factors on the term of an experimental interaction when the experimenter cannot control non-verbal social cues he emits? A robot, whose behavior can entirely be programmed, constitutes a useful tool for this level. Authors' purpose is to expose a new method, accessible to all and neophytes in computers, which can be applied to a humanoid reactive robot for scientific research. Harel's "statechart" bring a formalism allowing deriving from it a program in which the states of the artificial system can be modeled in terms of states-actions. The technics and advantages brought by this proposed method will be reviewed through the illustration of two studies: the first one focusing on inclusion processes in younger children, the second one on the endowment effect within a sample of adults.

Keywords—Human-system interactions, reactive systems, humanoid robots, embodied robots, HRI, NAO, social norms, pragmatics, relevance theory, politeness rules, cognitive bias, decision making, class inclusion, endowment effect

I. INTRODUCTION

When the role of robots becomes more important within humans' environments, current research is only beginning to be extended to the study of its impact on the character of social relationships. Do errors of judgment associated with some human interaction contexts persist when individuals interact with a humanoid robot? This paper provides a building block to identify non-verbal cues, programmable in a robot, that are able to activate social norms in a human-robot interaction.

A. Robots as sociable entities

Literature reports of studies showing that human-robot relationships can become social when adequate criteria are met, particularly with humanoid robots. There is also a strong tendency to anthropomorphize robots, which is to say, lending to robots human thoughts and emotions [12]. This is paradoxical in studies, as participants know that they interact with a robot. This anthropomorphism would respond to a primary need to recover a satisfactory state of familiarity in the

situation of interaction and is independent of technological knowledge [1].

Between humans, the action to influence another person is crucial for just about any type of social relationship [8]. The literature on robotics has identified a number of factors that could make a robot appearing more sociable and influences the behavior of the user:

- Appearance and behavior: level of presence - physical or non-physical [2]; the gender of the robot - male or female [11], [9].
- Modalities of interaction: the robot must be able to interpret and reproduce the non-verbal cues of his interlocutor (body language, eye contact); the interaction between robot and user must extend the senses to sight and touch [31], [32].
- Autonomy and interactivity: the robot knows how to take decisions in a given situation, without the needing a human intermediary [33].

These factors influence many behavioral dimensions in human contact, including:

- Fun [6], [5],
- Cooperation in action [26],
- Trust and respect shown to the agent [7],
- The general perception of the presence of an artificial agent or robot's [5].

B. Benefits to use a robot to test social factors in interaction

Humans' capacity to behave socially with other social individuals makes them able to treat artificial intelligent agents as social entities [24]. As social norms can be defined by interactions between people, they can be defined by the interactions between humans and robots [8]. By analyzing the factors enabling social norms among humans, we can recreate those factors or controlling them by applying them to a robot.

Another benefit in using a robot is that it could endorse different social roles regarding its programmed behavior, impacting the social context of interaction.

Thus, by using a robot we can further analyze the impact of each behavioral factor, alone or in combination, on a socialized relationship between human and robot. This last feature offers new possibilities in the study of biases observed in social relations, including the “endowment effect”, as a widespread

Some recent studies use this offer to analyze human cognition in interaction with robots by manipulating a whole set of factors, showing that to study human cognition with robot is not such an abstract idea. These show that humans have a tendency to implicitly consider computers as social actors when individuals are invited to through subtle clues [16]. This tendency was named “media equation” [24] and has been analyzed by applying some categories and social behaviors as for example gender and cooperative feeling with computers [16].

More recently, this phenomenon was applied to HRIs [29]. For example, the manner by humans respond physically to robots is exactly the same than in front of another human. Specifically, proxemic distance that takes place between humans and robots is identical than in interactions between humans interactions [24]. Moreover, research on proxemical distance in human-robots interactions show that this factor can impact interactions as it would do within between humans’ interactions [8].

Bateson suggests [6], according to his “double-bind” theory, that inconsistency in human communication can produce mental illness. Findings of Nomura showing that inconsistency between postures and verbal statements emitted by robots can impacts reasoning and memorizing, particularly in a specific combination: impolite posture and polite statements. Results of Nomura’s study and others imply the possibility of an interaction between different several factors in HRIs [17].

Studies mentioned above focus on comparisons between human-robot interactions and human-human interactions, in terms of impact on quality of interactions and social perceptions. These works often use new methods to do it. Another branch of research is interesting by reuse some existent methods to show differences of cognitive performances during an experimental task. Thus, non-verbal behaviors as gestures and body postures, and the context of interaction, are important factors in human communication.

C. Well-know paradigms reviewed with robots to study social norms – towards a new paradigm with robot as experimenter

In psychological experiments on reasoning, probability judgment and decision-making, numerous evidences underlined the importance to the pragmatics and to contextual implications in the participants’ inference and behavior induced by human experimenters (see for example [12], [3], [19-22], [25], [28], [27]). Especially, these pragmatismal and contextual factors can explain a different interpretation or

representation of the task for participants where outcomes would be the result of compliance with social norms¹.

In order to place individuals in a totally neutral and disambiguated environment, the use of a humanoid robot in place of the experimenter constitutes a very good tool. This methodology allows feedback to finely control contextual and cues which can cause pragmatismal effects. Retrospectively, several applications in human-robot interactions are expected.

Going further in this prospect, some authors started to study some biases analyzed since a long time from a totally new point of view: pragmatics of language and social context [2].

In this paper will be presented two particular examples where a robot was used as experimenter within old paradigms to make experiments in cognitive psychology. This new way to use these paradigms could bring some important elements to psychology and retrospectively to robotics, to know how a robot can be programed to behave properly in specific situations. Our team studied two elements which are very important for psychologists: class inclusion and the endowment effect.

We based on these two elements to build a methodology in order to test impacts of pragmatics on results previously founded in literature, applicable to all psychological processes studied implying politeness rules and pragmatics.

Thus, pragmatics in the standard inclusion task with children will set an implicit situation which suggests to the child that the experimenter expects some good results from him (theory of relevance [27]). This task is one that allows to test the impacts of pragmatics on a very simple task with young children.

In the paradigm of exchange with adults to measure endowment effect, pragmatics plays a role in the attribution towards the experimenter that he is expecting a polite answer form the participant [15].

This choice was oriented towards politeness rules and pragmatics of language in the fact they take place in a lot of everyday life situations and have a lot of applications in psychology, in robotics and in economy [10], [11]. We could so generalize it to other experimental situations where politeness rules and pragmatics of language could lead to some error in reasoning or decision making. Then these new results will be interesting for robotics to create more sociable robot behaving as to reproduce natural human behaviors and reasoning as humans would do.

1) Class inclusion with children

Thus, we analyzed the capacity of class inclusion with younger children, previously tested accordingly to Piaget’s theories on stages of development, regarding social context and pragmatics of language [31], [18].

Endowment effect has also been studied according the paradigm of exchange [13] with adults by manipulating social context and norms. The originality of these works is to study

¹ The question of the implication of social norms for economical decisions is studied since a long time in philosophy and in economics (see for example [10])

well known biases along years with new technics, using recent technologies. Piaget's theories suggest that when children do not have met a development stage called "concrete operations", including the operation of classification, children cannot be inclusive. The experimental initially used to test capacities of class inclusions with children consists to ask them to compare a super category with a subcategory. For example it is asked to the child if among objects presented in front of him (tulips among another kind of flowers): "Are there more of tulips or are there more of flowers?" [18].

If children are inclusive, so as for Piaget, once the adapted development stage is passed, they will answer by telling there are more flowers than tulips, in contrast with children who are not inclusive and could only compare categories on an horizontal level, for example "tulips" and "roses".

2) *The endowment effect with adults*

The endowment effect is another process, constituting a "bias" in decision making that we are investigated by using methods presented here. The endowment effect [30] consists to attribute a larger greater value to an object when we own it, than when we do not own it. This "bias" is very often measured according the paradigm of exchange [13], grouping three experimental steps:

- The experimenter gives an object A to the participant.
- Then the participant makes a masking task, usually consisting in a treatment task during about fifteen minutes.
- The experimenter comes back in the session room and asks the participant whether he would change or note the first given object A against an object B about an equally economic value.

This experiment is led into a second independent group where objects A and B are permuted. According to this method, the level of the endowment effect produced is measured along the refusals' rates in front of the proposition to exchange the given object against the second one.

In a very large literature on this subject, factors emerging to produce this effect are the "loss aversion" [11] and the phenomenon of "ownership" [23].

Through these two kinds of processes, we will then show how to program a robot to lead associated experiments. This present work makes a good illustration to show that another benefit to use a robot is it can be applicable to a large panel, going from children to adults.

II. A NEW PARADIGM FOR NEW HYPOTHESES

In these different studies one question remains that is to make results affordable if we want to finely test the impacts of social behaviors on effects measured. A social interaction is not only based on verbal contents exchanged between interlocutors, but stands on social non-verbal clues emitted which are out of control of protagonists.

How to evaluate the impact of implicit factors on the measured effect when the experimenter cannot control all of the clues he emits in front of the participant?

It is here that a humanoid robot can be a very useful tool since it is possible to entirely program its behavior, so as to annihilate all social cues or to artificially recreate it in the robot. It is possible to preprogram a robot to make him behaving autonomously during a whole experimental session but they are many technical constraints, as for example:

- Speech recognition module cannot perfectly understand all kinds of voice in all configurations.
- Then, the program has to process some statements in a limited set of forecasted words in the experimental situation.
- The visual recognition does not work perfectly.

These different constraints make it difficult to reach the end of the experiment with a perfect behavior.

Studies using robots, as well as some studies presented in introduction, often use a technic called the "wizard of Oz" methods. This term, usually met in literature means that when participant faces a robot, this one is tele operated from another room, unbeknownst to them. A major advantage of this technic is that experimenters can leave the participant alone with the robot and make it appear totally autonomous.

A lot of technical constraint still existing, this method has the advantage of allowing a whole experiment lonely with a robot, without the presence of any human in the experimental session's place, while avoiding lost results where a totally preprogrammed autonomous behavior could stop or malfunction during experiments.

Whereas this technic is now well known in research, it has the disadvantage to break one of basic offer that was initially brought by robots, that is to say a perfect standardization of actions led by the experimenter. In wizard of Oz methods, the robot which leads experiments is always directly tele operated by a human, so rhythms of gestures are never exactly the same.

In this present work, a hybrid method is used to simultaneously preserve standardization all by avoiding all malfunctioning. We will go through two concrete examples brought by the measure of endowment and show that these methods allow to test new hypotheses to test inclusion among children and the endowment effect among adults.

First, we assume that inclusion errors made by children in the inclusion task of Piaget's study not only depend on the factor of age but largely on social context: the inclusion task is usually led by a teacher which is implicitly perceived by the child as a social entity in front whom he has to give the good answer [4].

Then we assume that the level of the endowment effect measured according the experimental situation of the paradigm of exchange by Knetsch is more due to social factors: politeness rules engaged in the human participant-experimenter interactions prohibit to change a given object - considered as a present in our culture - against another or to refuse this gift [15].

To test these new hypotheses regarding well known processes in literature, we use a robot NAO (Aldebaran) to

design an hybrid experimental technic that takes a place between wizard of Oz method and a fully previously programmed behavior.

III. METHODOLOGY

A. Materials

Both experimental sessions are led by a humanoid robot NAO (Aldebaran version 4 – “Evolution”). The behavior of the robot is programmed with the software Choregraphe in version 2 built by Aldebaran, and stored on a laptop connected to the robot via Wi-Fi from another room.

The advantage of NAO is that it can reproduce all needed experimental gestures that would be expressed by a human experimenter. Thus the NAO robot possesses 25 degrees of freedom, allowing him to move its limbs as a human. Then, this robot’s appearance is not too closed than humans’ and we can assume that no other uncontrolled factors as anthropomorphism or uncanny valley effect affect results [14].

The robot also owns two hands making it able to hold little and soft objects (see Fig. 1).

We can list the embedded useful modules needed as following:

- A vocal synthesis: allow the robot to make verbal statements to the participant and to explain him the experimental procedure. This module is useful for example when it is wanted to keep neutral vocal intonations.
- The possibility to store audio files in the robot makes it possible to pre-record vocal statements by making them identical form humans’ voice.
- The robot is sensitive to noise and owns sensors: these capacities allow the robot to be autonomously responsive to the behavior of the participant
- A camera is embedded in the head of the robot: as this camera can be used for objects’ or faces’ recognition, it is used here to see the behavior of the participant by distance, as facial expressions for example.

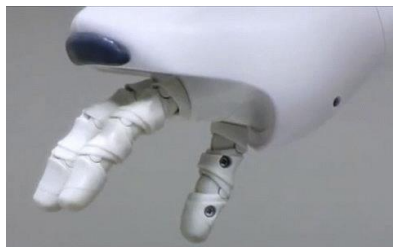


Figure 1. Picture of one NAO’s hand

B. Procedure with a “semi-wizard of Oz” method

So we reproduced the two main experimental situations as described in introduction by replacing experimenter by NAO. In each situation, robot can launch from another room unbeknownst to the participant:

- Class inclusion task to test class inclusion with 20 children.
- The paradigm of exchange with 40 adults.

In the paradigm of exchange, two conditions. In “neutral robot” condition, the robot was presented as a simple tool to collect data, and all non-verbal indices were controlled to be annihilated. In the “sociable experimenter robot” condition, all these non-verbal indices were reintroduced: gazes, participants face tracking, vocal intonations.

IV. DESIGN OF A NEW PROCEDURE, STARTING FROM “PAPER” TO EXPERIMENTAL SESSIONS

Works presented here focus on the methods used to permit a whole experiment with a solely robot in the room interacting participant, without breaking a perfectly standardization in actions conducted. One thing important here is that the same approach can be used, both with very different topics : inclusion and endowment effect, and on another side both with very different samples: adults and children.

A. Harel’s statecharts

Statecharts (SC) of Harel, included in UML approach, bring a formalism to represent all different steps state-action during a procedure. This model meets some advantages listed below:

- SC are adapted to all reactive system: it takes in account actions of the participant regarding the system, that may change its status.
- SC can be decomposed in several sub-statecharts: that allows focusing on several levels in the model of the system.
- SC can show all configurations in a system at different several times. So SC take in account all dynamic operations of the system.
- SC are easily readable, including neophytes for new technologies.

Here, these points are interesting because SC allow us to take in account the technical constraint of a robot and to prevent possible hazards which can occur in experimental sessions.

Mostly, a high difficulty for an autonomous robot is to capture all reactions of a human participant. For example, speech recognition or visual recognition are as much as hazards which could impact on the quality of experimental sessions: when it is crucial to wait for a precise response from the participant, it may be a risky way to use directly the vocal recognition module to catch the expected signal to continue, when the following of experiment is important for the study.

In the case of inclusion, robot often catches children enunciated words with difficulty.

So, what we propose is to articulate the statechart model around these constraints, that is to say participant’s actions which can encounter some technical limits of the robot.

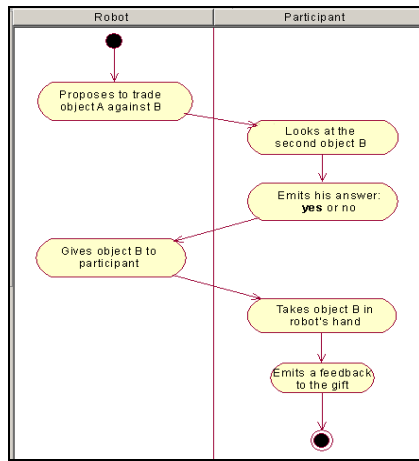


Figure 2. Simplified example of statechart used in the paradigm of exchange, at the step of proposal of exchange

SC take account of the expected action of the participant, which is to give his answer regarding the proposal enunciated by the robot to trade the first given object against the second one (see Fig. 2).

B. From statecharts to the programmed behavior

The software Choregraphe is very well adapted to derive statecharts in programmed behaviors, in the way it takes account about the same elements: actions of the participants, status and actions of the NAO robot. Choregraphe is also useful because it allows experimenters to launch different parts of the program in an independent way.

So, first we have several statecharts corresponding to all parts of the robot's behavior. Then these part-statecharts are derived in Choregraphe in subgroups of behaviors (see Fig. 3).

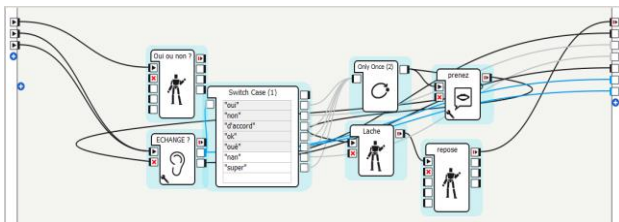


Figure 3. Capture of Choregraphe software (Aldebaran) based on a statechart (see also Fig. 2)

Statecharts take in account of different states of a system regarding stimuli of the environment. It is possible to derive it in Choregraphe thanks to entries corresponding in responses received by the robot's sensors, then to launch useful following simple actions. This kind of development is called event programming

This point is crucial in our methods because these different subparts can be launch separately. This presents real advantages:

- Each part or sub-behavior can be launched at any time: for example, when robot is giving instructions to the participant, when this one does not understand them, he can express it in a whole set of very different ways. Then, if the "giving instructions" step is grouped in an

isolate sub-behavior, the experimenter can launch again this block of actions as many times as it is necessary to make the participant understand the rules.

- At any time, the experimenter can choose the part that will be launched, even in a same step. This advantage offers three other points :
- Even if the step consists in giving rules of the experiment to the participant, it is possible to make some variations in the statements enunciated, maybe when the participant would understand the same rules but in a different presentation.
- When the robot is waiting for an answer of the participant, this one can emit different words. In that case, we have to pre-record different sub-behaviors, accordingly to each step, to ensure that the NAO's behavior will well adapt to each participant.
- Initially, in all experimentation in this kind of procedure, these are the actions of each participant that gives the rhythm of experimental session, not directly by the experimenter himself. Thus, acting in this manner will allow the robot to behave accordingly to the rhythm of the participant in each step.

These advantages draw a new paradigm in the use of robots in experimental tasks by allowing:

- To keep a perfect standardization in actions during each step: even when the experimenter can choose the subgroup of behavior which will be launched at specific times, actions include in this block are preprogrammed, so the experimenter keeps an entire control of actions which will be engaged by the robot. It is interesting for us here, because all social cues emitted by the robot experimenter will be will all be controlled.
- If the main program is well built, it can just let to experimenter all the appreciation of the experimental situation to know what to execute to continue on in the best way to lead the session at its term.

So, to summarize here, were are not completely in a magician of Oz technic, nor in the use of an entirely preprogrammed main behavior in a purpose to make the robot autonomous and to let it all conduct by itself.

V. EXPERIMENTAL TRIALS

A. Physical configuration

NAO:

In both experiments - inclusion and endowment effect - the robot NAO is sitting in front the participant, so as to keep is gaze at the same level than participant's one (see Fig. 4 for inclusion and Fig. 5 for endowment effect). In these two experiments, each participant was left in the room with the robot, presented as acting autonomously.



Figure 5. Picture of an experimental session in inclusion task



Figure 6. Picture of an experimental session in the paradigm of exchange.

In each configuration, NAO can move its arms to make all useful gestures during the experiments. In the experiment on the endowment effect, NAO holds the first object in its right arm and the other one is hidden beside its leg so as when the participant faces it, he cannot see this second object. In the inclusion experiment, NAO is sitting in front of the child, and between them fruits are disposed on a table in an apparently randomized way.

Human experimenters:

In both experiments, one experimenter is placed in a separate room to tele operate NAO. This experimenter can follow in live all situations with the embedded robot cameras which face the participant. In the task of inclusion, two human experimenters were needed, one of them to introduce the robot to the child, the other to prepare and launch the program.

B. Conditions

In the task of inclusion, the experimenter accompanying the child in the room containing the robot shows the robot as to be very stupid. Thus, the child is placed in the role of a teacher for the robot. Once the session is launched, the robot tell the child that he will teach him a lot of things, and starts by asking what are the different objects disposed on the table. Once the child has named all kinds of fruits, the experiment can continue on with the classic situation of the inclusion's task.

For the endowment effect, it is a little different in terms of procedure. There are two interesting conditions with opposite behaviors held by the robot: "neutral experimenter" robot and "sociable experimenter" robot.

In the "neutral" robot condition, NAO is programmed to behave in a way to annihilate all non-verbal social cues: it does not track the face of the participant; it does not more gestures that it is necessary and vocal intonations are almost nonexistent

and are only there to make the artificial discourse understandable with some punctuation. In this condition, only the speech synthesis of the robot is used to make statements. Also, the robot is shown as a simple mechanic tool to help human experimenters to collect data. In the "sociable" robot condition, social non-verbal cues identified in the literature are artificially implemented in the robot. Cues are listed below:

- NAO tracks the face of the participant
- NAO blinks rancorously during all the interaction
- NAO's speech is filled with vocal intonations from pre-recorded MP3 files, made by a human with all natural intonation, but arranged to keep nearly the same voice than in "neutral" condition.

In that second condition, social context is also manipulated for NAO is shown as a real collaborator which works directly in collaboration with human experimenters, as a social being.

VI. FIRST RESULTS AND DISCUSSION

According to previous studies on inclusion and endowment, the measured dependent variables are the same that in literature using this procedure with human experimenters for both studies: the Piaget's task of inclusion and the endowment effect. To reproduce these procedures by using a robot allowed us to manipulate two further classes of factors:

- Social context: as the robot appearance is near human's one but not the same - so the participant keeps in mind that he faces a robot - this makes it possible to introduce him as for example a stupid being, in the task of inclusion, or as a simple mechanic tool to collect results in the neutral condition in the paradigm of exchange.
- The social behavior of the robot: this variable was manipulated for the endowment effect experiments in which there are two behavioral conditions. In the "neutral" robot condition, NAO was programmed so as to behave neutrally, annihilating all social non-verbal cues. In "sociable" robot condition, social non-verbal cues have been artificially implemented to the robot.

These offers brought by the use of a humanoid robot allowed us to test a new kind of factors producing the endowment effect with adults or impacting results in the task of inclusion: social norms activated automatically in all interaction with some entity assuming a specific social role - or not.

In the task of class inclusion with 20 children, the first results by pilot sessions using new technics reported here tend to show that more younger children (close to 50%) were inclusive than in the Piaget's standard condition. These findings are interesting, showing that in some case social role endorsed by human teachers can impact learning with children. In experiments focusing the endowment effect, the both conditions, "neutral experimenter robot" and "sociable experimenter robot", show that the two factors listed above, the social context exposed and the robot's behavior, can nuance the level of the endowment effect produced. The fact that we

always use the same robot, only its behavior and social context can explain differences found in results.

There are notable differences between the two conditions regarding rates of refusals to the exchange proposition. These results tend to show that different artificial behaviors could annihilate or could enhance an endowment effect. In the sociable condition, refusal rates are significantly higher than acceptances', so an endowment effect is measured. In that last condition, social non-verbal cues are emitted by NAO. Thus, it shows that these cues reactivate social norms, which are expressed here by the respect of politeness rules in destination of the robot. Thus in this case we find a repartition close to those found in literature [9]. These results are beforehand useful for psychology for they finely show how social factors can impact on measured data. These results will also be useful in robotics in the fact they bring interesting new data on behaviors to implement to a robot to annihilate or minimize some cognitive biases. Especially, vocal intonations are a main factor to nuance social norms activation for the situation of paradigm of exchange [13].

VII. CONCLUSION

These two illustrations using a robot to test the inclusion with younger children and the endowment effect with adults allowed explaining well-documented processes in literature regarding a new class of factors: social context and pragmatics of language.

Findings emerging from the new methods presented here are very interesting in psychology, but have the double advantage to make this useful in all fields linked to reasoning and progress in robotics.

Technics presented here, that is to say a new approach situated between the wizard of Oz method and an entire programmed autonomous main behavior; make it possible to finely measure the impact of sub-behaviors, which can be used separately on in combination, on whole sets of processes where social norms could play a role. Moreover, technics used are accessible and do not require to be an expert in computer sciences. Statecharts' formalism of Harel, combined with software as Choregraphe permits to control each experimental situation by a high degree of control in the standardization of the procedure.

Further to the study of human factors which can bring to reasoning biases in everyday life within human interactions, these new technics allow us to isolate non-controlled human behaviors, finely identifying those which can improve learning or by contrast annihilate social cues which may induce biases in reasoning or in making of decisions processes.

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