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Impact of Head Motion on the Assistive Robot Expressiveness - Evaluation with Elderly Persons

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Abstract

In the near future, robots will support human to perform tasks in many domains (industrial, domestic, educational and health tasks). Such robot behaviors need to take into account the social interaction between robot and human. In this context, we focus on the expressiveness of a moving head for an assistive robot for the elderly. We designed a new moving head for the *Kompaï* companion robot. On one hand, this new head improves its perception capabilities. On the other hand, we expect to jointly increase its social skills and thus its acceptability. This new head is composed of a tablet to animate a virtual face according to 4 facial expressions and a mechanical neck with 4 degrees of freedom to enhance the robot's expression. Before improving face expressions and adding more complex head movements, it is essential to evaluate the combination of simple head movements with virtual face expressions. A study was held jointly with physicians (psychologists, ergonomists) at the Broca Hospital in Paris to assess the impact to combine head movements with virtual face expressions, and the global acceptability of the *Kompaï* head by the elderly.

1 Introduction

After industrial application, recent improvements in robotics will lead in the near future to an increased role of robots in many news domains: domestic, educational or, as seen more recently, health tasks at home. Robots are increasingly seen as potential companions for everyday life. As stated by Dautenhahn in [1], *"A robot companion in a home environment needs to 'do the right things', i.e. it has to be useful and perform tasks around the house, but it also has to 'do the things right', i.e. in* ***a manner that is believable and acceptable to humans"***. To meet these requirements, a robot must have abilities to interact socially with humans. Two kinds of inter-correlated interactions are important for Human-Robot Interaction (HRI): physical interaction and social interaction. Physical interactions have been extensively studied for manufacturing use, medical use, etc. Social interaction is particularly challenging and needs to consider two points of view: 1) Interpretation by the robot of the human intentions, and 2) Interpretation by the human of the robot intentions. The first point requires databases of human interaction in different contexts where each data is annotated. These databases are the input of machine learning techniques (computer vision and multimodal perception domains). The second point is based on human interpretation. The only way to evaluate the contribution of proposals is to perform experimentation with human using methods from ergonomics.

In earlier work, we addressed embedded perception of humans [2] on companion robots. For this perception task, a new head was designed for *Kompaï*, a companion robot. *Kompaï* (Figure 1) is manufactured by Robosoft[1]. Its dimensions are 140 centimeters in height and 55 centimeters in width. *Kompaï* is a mobile robot which can either act autonomously or be driven by a user using a remote control or voice commands. It is equipped with various sensors for its environment: Lidar, infrared and ultrasonic telemeters, cameras, RGB-D sensor (Kinect 1). Using these sensors, *Kompaï* can perform elementary actions such as locate itself in the environment, stop before obstacles, and detect people. Its new head is based on a tablet with front/rear cameras and servomotors to mimic neck moves. Moving the head and looking at a specific position can improve

[1] `http://www.robosoft.com/`

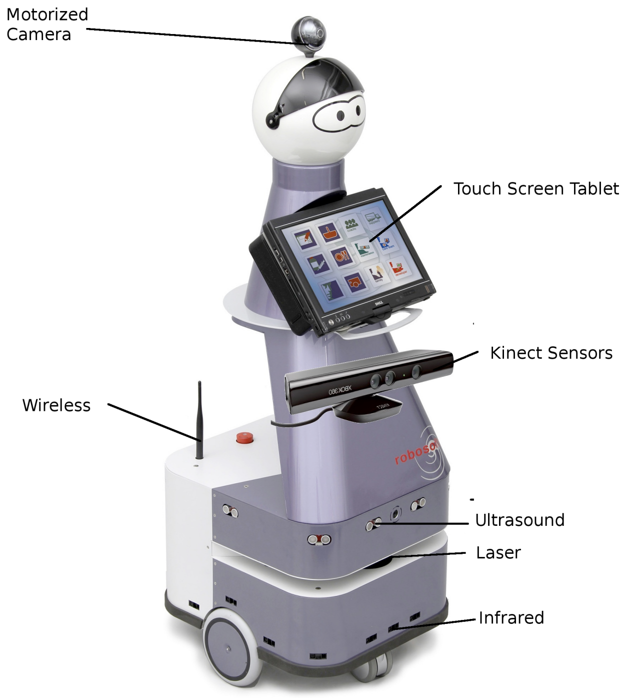

Figure 1: *Kompaï* is equipped with a laser range finder, ultrasound and infrared telemeters, a tablet PC, a camera in its base, a webcam on top and a Kinect on the torso.

detection of objects, human faces, bodies or hands. This allows the robot to anticipate interaction by rotating the head and align the robot's gaze with its human partner.

In this article, we address the impact of this moving robot head in the interaction loop with human. More precisely, in the context of a companion robot interacting with elderly people, we want to evaluate if head movements:

- do not disrupt perception of expressed emotions;
- can improve expressiveness of the robot, thereby improving its overall acceptability.

We describe the results of a study conducted jointly with physicians (psychologists, ergonomists) at the Broca Hospital in Paris in early 2015. In this study, we have evaluated several criteria: qualitative evaluation of the emotions expressed by the robot, impact of movements on the emotion expression and global acceptability of the robot head.

In the following, Section 2 presents related works. Section 3 describes the design and technical implementation of the expressive moving head. This is followed by a section on evaluation protocol and the results of the study with elderly people. The paper ends with conclusion and perspective.

2 Related Works

As robotic technologies progress, an increasing number of studies have addressed the impact of design on human robot interaction. Such studies often use a Wizard-of-Oz technique (WoZ), as in [3, 4], combined with user interviews on specific key aspects of the experimentation [5]. [6] and [7] have shown that the shape of the robot and its autonomous movements have important influence on the anthropomorphic perception of the robot. Several experiments have demonstrated that even simple devices, such as cleaning robots, can elicit empathy in humans [8]. This tendency to "*anthropomorphize*" is even more important with humanoid robots and increases expectations for overall performance [1].

Numerous companion robots can be found in the literature [5, 7, 9–13]. Such robotics can be grouped into 3 categories. The first group includes pet robots. Historically, the dog-like Aibo, was the first pet robot sold at large-scale, with early models reaching the market in 1999. More recent examples of this category include iCat, Paro (a baby seal) and Pleo (a dinosaur). The second category contains utility robots, usually with some anthropomorphic attributes such as gaze, head movement, facial expression, and arm gestures. In this category, one can find Sparkly, IROMEC, Pearl, Robotcare, Care-o-bot, Max from the Serroga project, the *Kompaï* used

Figure 2: New design for the robot head. Left, the original head, right the new design with a tablet.

in this project as well as the Aldebaran Pepper. The last category includes humanoid robots such as the NAO, KASPAR, a small child robot, and the Geminoid series, a series of humanoid robots used for telepresence.

For the design of the head of a companion robot for elderly people, we drew inspiration from robots in the second category. The first inspiration came from Sparkly [7], a small mobile robot with an expressive head. By changing the shape of metal wires on its face, it can express several emotions: *happiness*, *sadness*, *surprise* and *anger*. The IROMEC robot is similar but a screen replaces the metal wires. The facial designs of both robots are easily understandable with their smiley design. Other robots could be more massive, almost at human size, with an increase social presence. Care-o-bot is a companion robot comparable to the *Kompaï* robot. It is not anthropomorphic but has a mobile torso. In a user study [14], joint attention was elicited by rotating the robot's torso to simulate gaze direction. Results demonstrated that participants preferred this condition and that movements increase the social impact of the robot. Within the Serroga project, an evaluation of *Max*, a companion robot for elderly, has been conducted [5]. Its design integrates a topped head with 2 expressive eyes but no neck. *Max* was tested from 1 up to 3 days at home with elderly people. Beyond the functional evaluation done in this experiment, participants demonstrated acceptance of the robot as a health assistant and as a social companion. In their conclusion, the authors state that "*robots provide psychosocial and instrumental advantages due to their embodiment, mobility, and social presence.*".

Several studies have been conducted with Nao, KASPAR and some other robots [9–11,15]. The results indicate that head, gaze, embodiment and movements have an impact on the social presence and on the acceptance of the robot.

3 Experimental device

The original head of the *Kompaï* is a plastic spherical head with a camera on top. Based on state-of-the-art results and our own past experience [16], we made several design choices to replace it. The new head is composed of an Android tablet mounted on a mechanical neck. Figure 2 depicts the plastic spherical head and the new head.

3.1 Facial expression design

The Android tablet displays several animated facial expressions according to the situation and the selected visual design. For the design of the expressive face, we compared the smiley approach used with Spackly and IMOREC (see section 2) with a virtual agent approach called *Louise*. The *Kompaï* smiley design[2] was inspired by the original plastic head design. The virtual human face used in this study is from the virtual character *Louise*, meant for a future version of an assistive embodied conversational agent project [17]. The character model was created using Autodesk Character Creator and the expressive face images were created by animating and rendering this model using Autodesk Maya [3].

In our context to assess the impact of an animated robot head for elderly people, we choose to study the following basic emotions: *happiness*, *sadness*, *surprise*, *anger*. Figure 3 shows the facial expressions for *Kompai* and for *Louise* faces. An unpublished internal evaluation about *Kompaï* facial expression recognition has been conducted on 156 persons from 6 to 89 year old, half female/male and 90.77% right-handed. Recognition rates were 97.92% for *happiness*, 77.93% for *sadness*, 81.41% for *surprise* and 93.39% for *anger*.

[2] The smiley faces were provided by the Robosoft company in collaboration with Inria researchers.
[3] `http://www.autodesk.com/products/maya/overview`

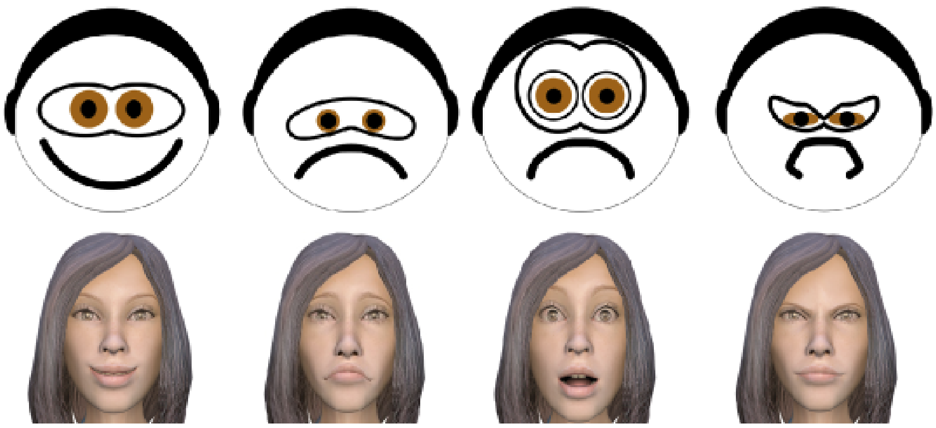

Figure 3: *Kompaï* and *Louise* expressive faces designed for Android tablet application. From left to right, one can find *happiness*, *sadness*, *surprise* and *anger* expressions.

3.2 Mechanical neck design

The objective is to animate the robot head to combine facial robot expressions with a neck movement like human behavior. The mechanical neck is composed of 4 servomotors: 1 in the base for rotation, 3 in the upper part for movements. The mechanism is closed to the robot used in human honesty experiment by Hoffman et al. [18]. The neck is in constructed from wooden and was made using a laser cutter. The "L" shape allows the head to lower onto its neck. It also acts as vibration absorber without power consumption while the robot is moving. Figure 4 depicts the mechanical design of the *Kompaï* head.

To control the mechanical neck, we developed SmartServoFramework[4], an open source project freely available. This framework lets us control movements for all expressions using widely spread servomotors, in this case Dynamixel© servomotors. Gesture associated to facial expressions can be described as follow:

- the *happiness* movement moves up proudly;
- for *sadness*, the head moves to look down;
- *surprise* consists of a recoiled movement;
- to express *anger*, the head goes forward and nods laterally.

In order to be comparable, these movements are the same for *Kompaï* face and *Louise* face.

3.3 Wizard of Oz and head remote controller

Based on a REST architecture (*REpresentational State Transfer*), in this study, the expressive robot head can be remotely controlled by a Wizard-of-Oz (WoZ) experimenter using a smartphone application (depicted on figure Figure 5). It is possible to switch between *Kompaï* face and *Louise* faces, or to activate the head animation associated to each facial expression. The experimenter can choose which facial expression to play. We added 2 joysticks (4 degrees of freedom) to control the neck. Using these joysticks the experimenter can dynamically change the behavior of the robot. For example, one can give the illusion that the robot is looking around to find a person.

4 Evaluation and discussion

4.1 Assessment protocol

We conducted collective and individual assessments at the Broca Hospital in Paris supervised by computer scientists and physicians (psychologists and ergonomists). To assess the acceptability of our mobile expressive robot head by elderly people, we retain several criteria: qualitative evaluation of the emotions expressed by the robot, impact of movements on the emotion expression and global acceptance of the robot head. Movements associated to the facial expressions are quite short. To reduce impact of the presentation order, each stimulus was played randomly several times.

[4] https://github.com/emericg/SmartServoFramework

Figure 4: Head mechanical design. The head is built with 4 Dynamixel© servomotors, laser cutted wood and Plexiglas for the structure and the tablet support. During experimentation, the neck is covered with a textile muff.

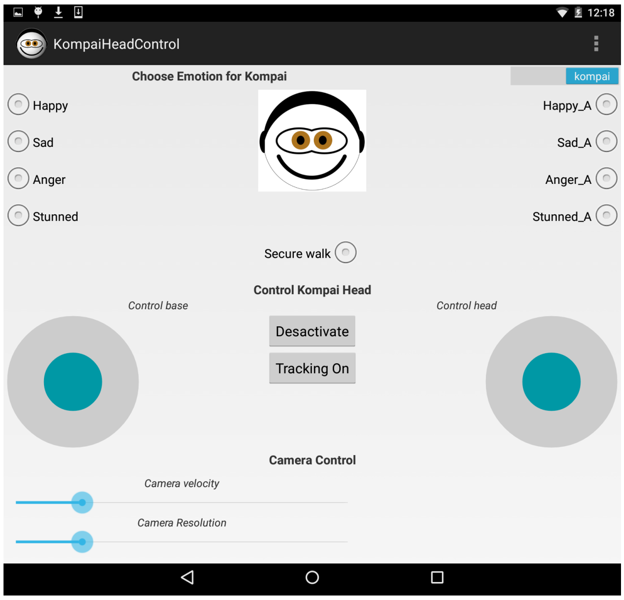

Figure 5: Remote control of the expressive robot head. Using this remote control, the experimenter can switch from the *Kompaï* to *Louise* rendering, launch predefined animations and control the 4 degrees of freedom of the head.

4.1.1 Gathered information

To compile sociodemographic data, all participants were asked to complete a form relative to their situation: age, gender, education, marital status, monthly income and work situation (see table 1). Participants had to meet several criteria to be included in the study: be over 54 year old, be in good cognitive and physical health, without severe visual or hearing pathology, and must understand French.

Each participant assessed the robot head's expressiveness with and without head movement. To remove issues related to technical vocabulary, we asked participants to associate an emotional state to the expressive head using a word of their choice for all 4 conditions: *Kompaï* or *Louise*, with or without mechanical animations. These words were tagged by a psychologist according to the semantic proximity between the word and the robot's expression. We retained 3 semantic distances: *irrelevant concept* when the word is out of the semantic field of the facial expression, *close concept* when the word is in its semantic scope but does not match with it, and *correct concept* when the word is relevant.

At the end, we asked participants to complete a survey asking information about their perception and acceptance of the robot head. All the sessions with elderly participants were recorded and annotated by psychologists. These annotations are useful to get free comments from the participants about the robot in context.

4.1.2 Collective assessment

The collective assessment was organized as a discussion on the topic of "Robots and expressiveness". The first step was to familiarize the elderly subjects with the robot *Kompaï*. Afterward, an open discussion was held about the requirements to improve the quality of robot-human interaction using an expressive head. Underlying topics are acceptability and usefulness of such head. The discussion was oriented towards the expressiveness of a robot head with a mechanical animation associated to a virtual animation of the face (discussion about ergonomics and behavior of robots in human-robot interaction).

For this experiment, 7 participants (6 men and 1 woman) were supervised by 3 physicians (2 psychologists and 1 ergonomist) of the Living Lab and 3 computer science researchers. The session in the Living Lab lasted two hours. The participants assessed the way they perceived each emotion for each condition: *Kompaï* and *Louise*, with and without mechanical animation. They also compared these conditions with the original plastic

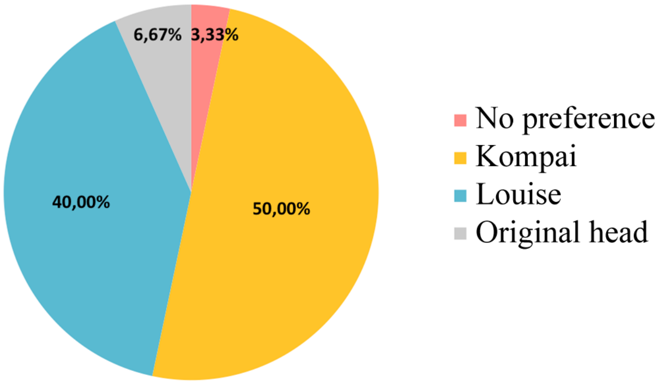

Figure 6: Preference among head version for the elderly.

Variables	Classes	Frequency (n=30)	Percentage
Age	≤ 70	15	50.00%
	> 70	15	50.00%
Gender	M	6	20.00%
	F	24	80.00%
Education	Primairy school	2	6.67%
	Secondary and high school	5	16.67%
	Higher learning	23	76.67%
Martial status	Single	17	56.67%
	Couple	13	43.33%
Monthly income	$< 2,500$ €	13	43.33%
	$> 2,500$ €	17	57.00%
Work situation	Unemployed	27	90.00%
	Working	3	10.00%

Table 1: Sociodemographic representation of participants

head. The results of these assessments are described in the section 4.2. Only 2 participants from this collective assessment appear in table 1 as we have not complete sociodemographic data for the others.

4.1.3 Individual assessment

We recruited 28 volunteers to take part in an individual assessment of the expressive robot head. The session took place at the Broca Hospital. Each individual interview was supervised by 2 researchers. The participants assessed the way they perceived each emotion for each face (*Kompaï* and *Louise*) with and without mechanical animation. And they compared with the previous plastic head. The results of these assessments are described in Section 4.2.

4.2 Results & discussion

As explained in the previous section, final results include 30 participants. Sociodemographic information of the sample is presented in table 1. Data shows balanced distribution regarding age (in range [54,90], half ≤ 70, $avg = 72.66$, $\sigma = 9.03$), marital status and monthly income. Males and higher education are respectively under and over represented. As expected for elderly people, only 10% are still working.

Table 2 presents the results of the expressive robot head assessment. For the *Kompaï* head with or without mechanical animations, happiness is the most relevant expression: 83% and 63% of participants correctly recognized this expression. For the *Louise* head with or without mechanical animation, surprise is the most easily recognized expression with correct recognition by 90% and 86% of participants. The *Kompaï* condition obtains its worst score (16% and 10%) for this expression with a high rating for the irrelevant expression (76% without mechanical animations and 86% with mechanical animations). In our internal evaluation of the smiley design (see section 3.2), the score for the static version of surprise shows a higher score (81.41%). From this,

Happiness	**Kompai (static)**		**Kompai (moving)**		**Louise (static)**		**Louise (moving)**	
	Freq.	*%*	*Freq.*	*%*	*Freq.*	*%*	*Freq.*	*%*
Irrelevant concept	3	10	6	20	10	33.33	9	30
Close concept	2	6.67	5	16.67	4	13.33	1	3.33
Correct concept	25	83.33	19	6.33	16	53.33	20	66.67

Sadness	**Kompai (static)**		**Kompai (moving)**		**Louise (static)**		**Louise (moving)**	
	Freq.	*%*	*Freq.*	*%*	*Freq.*	*%*	*Freq.*	*%*
Irrelevant concept	7	23.33	14	46.67	21	70.00	22	73.33
Close concept	12	40	2	6.67	0	0	2	3.33
Correct concept	11	36.67	14	46.67	9	30.00	6	20.00

Surprise	**Kompai (static)**		**Kompai (moving)**		**Louise (static)**		**Louise (moving)**	
	Freq.	*%*	*Freq.*	*%*	*Freq.*	*%*	*Freq.*	*%*
Irrelevant concept	23	76.67	26	86.67	2	6.67	4	13.33
Close concept	2	6.67	1	3.33	1	3.33	0	0
Correct concept	5	16.67	3	10	27	90.00	26	86.67

Anger	**Kompai (static)**		**Kompai (moving)**		**Louise (static)**		**Louise (moving)**	
	Freq.	*%*	*Freq.*	*%*	*Freq.*	*%*	*Freq.*	*%*
Irrelevant concept	5	16.67	11	36.67	22	73.33	22	73.33
Close concept	2	6.67	5	16.67	2	6.67	2	6.67
Correct concept	23	76.67	14	46.67	6	20.00	6	20

Table 2: Rating of the head expressions for each configuration

we have concluded that the surprise expression may have been improperly designed and should undergo a redesign. The sadness expression is quite balanced between the 2 versions. The anger expression is not well interpreted with the *Louise* head but it is unclear whether the expression design is weak for *Louise* or whether this expression is not well accepted by the participants.

The mechanical animation maintains the relevance for head expressions. But with the *Kompaï* head, mechanical animation can reduce the interpretation of the head expression. With the *Louise* version, this does not occur. Results with and without mechanical animations are very similar. While the mechanical animation does not modify the acceptability of the robot head, it also does not significantly improve its expressiveness.

From the data, one can observe that, with a relevant design of the facial expressions, the elderly interpret more easily a facial expression with a "smiley" face design rather than a virtual agent. This result matches with the participants' preferences depicted in Figure 6. Indeed, the elderly people prefer the tablet system at 90% with a small inclination for the *Kompaï* version (50% versus 40%). The original spherical head is less supported (6.67%).

To interpret more deeply these results, we run a bivariate analysis between the *Static* and *Moving* conditions for all facial expressions (*Happiness*, *Sadness*, *Surprise*, *Anger*). There are few significant differences to highlight. The motion is significant for *Louise* for the Happiness and Sadness facial expressions with *p-value* respectively equals to 0.003 and 0.008. For the *Surprise* and *Anger* expressions, the motion is significant for *Kompai* with *p-value* equals to 0.007 and 0.0009. All other comparisons are not significant. From these results, we can affirm that, in our experiment, most of the time there is no significant difference between static and moving conditions. In the few cases of a significant difference, there is a decrease of the recognition using motion except for *Hapiness* with *Louise* (table 2). As we write this article, we cannot definitely conclude about reasons of this deterioration. Several hypotheses could be envisioned: design of the motions associated to the expressions, flatness of the head or interdependence between tablet rendering and movements for instance. We are currently working on a new version of the robot to question these hypotheses.

Last, free comments from people provide complementary information about these results. For the original head, people like its 3D volume that "*let see the head from a 3/4 view*". The tablet is appreciated as it is more expressive. Within comments, there is no clear consensus about the anthropomorphism choice to make for the head. Some people prefer the *Louise* version precisely because it is anthropomorphic. Others said that the smiley version is better because it "*stays a robot*" and it is more playful.

5 Conclusion

In this article, we focus on social Human-Robot interaction from the human point of view. More precisely, we evaluate the impact of an expressive moving head for an assistive robot interacting with elderly people. The expressive moving head was designed with 4 degrees of freedom for our robotic platform. This new head is composed of a tablet that provides an animated virtual face according to 4 facial expressions and a mechanical neck to enhance the expressiveness of the robot.

To assess the impact of head movements combined with virtual face expressions, and the global acceptability of this head by the elderly, a study was held jointly with physicians (psychologists, ergonomists) at the Broca Hospital in Paris. This study compares a virtual 3D human character (*Louise*) to a virtual "smiley" face (*Kompaï*), with or without mechanical animations to gauge impact of movements. From the experiments we draw two conclusions:

- The recognition of the facial expressions by Elderly people is easier with a virtual "smiley" face design rather than with a virtual 3D human character;
- The mechanical animation maintains the relevance of expression. While it does not significantly affect the acceptability of the robot's head, it also does not improve its expressiveness.

These conclusions have raised several questions. Which neck movement associated to a virtual facial expression to improve the global robot expression? Are there expectations on the animation of the neck according to the virtual face representation (difference between *Kompaï* and *Louise* condition)? New experiments should be conducted to generalize the results. In addition, it would be interesting to create and to evaluate new head animations to complete these results.

6 Acknowledgement

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