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The physiological mechanisms underlying consumer preferences towards organic food

Giulia D'Adamo [a], Giulia Andreani [b], Martina Ardizzi [a], Francesca Ferroni [a], Doriana De Marco [c], Daniele Asioli [d], Giovanni Sogari [b], Maria Alessandra Umiltà [b,e,*]

[a] University of Parma, Department of Medicine and Surgery, Italy
[b] University of Parma, Department of Food and Drug, Italy
[c] Consiglio Nazionale Delle Ricerche, Institute of Neuroscience, Parma, Italy
[d] University of Reading, Department of Agri-Food Economics and Marketing, UK
[e] Italian Academy for Advanced Studies in America at Columbia University, New York, USA

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ABSTRACT

Previous research has shown that organic food labeling may lead consumers to biased processing of their preferences, the physiological mechanisms behind this phenomenon are not understood. For the first time, this manuscript combines consumer valuation and physiological measures to investigate the explicit and implicit preference dimensions of organic food. The explicit dimension was measured using the expected and actual degree of liking of two identical – but differently labeled – pear juices (organic and non-organic) while the implicit dimension was measured using the activity of the mylohyoid muscle (MM) and the 3D kinematics of the hand, and arm movements. Our findings reveal that the MM was activated during the pre-action phase, where participants observed the organic-labeled product, which suggests a selective anticipatory motor preparation. Moreover, kinematic analyses indicated that participants reached for the organic-labeled pear juice with a shorter reaction time and with more targeted grasping movements compared to the non-organic-labeled juice. In addition, the presence of the organic label significantly influenced consumers' degree of liking. Using this novel approach, these results contribute to a better understanding of the physiological mechanisms underlying consumers' behaviors toward organic food products.

1. Introduction

Consumers' food choices affect both human health and the environment (Clark et al., 2019). Currently, direct greenhouse gas (GHG) emissions from agriculture account for over 11% of global GHG emissions (OECD, 2022). In addition, food also impacts human well-being as it can potentially lower (or increase) the risk of non-communicable diseases such as heart disease, diabetes, and cancer, among others (Koene et al., 2016). Thus, the concepts of sustainable diets and production systems have spread into the global market, and consumers are increasingly interested in information about different product attributes (e.g. origin, nutritional components, processing information, etc.) and their relation to the environment and health (Asioli et al., 2017; Sultan et al., 2020; Gundala & Singh, 2021; Khan et al., 2023).

For this reason, healthful, sustainable, and ecologically friendly food systems are becoming a higher priority in many countries, both in terms of legislation and consumer behavior. For example, EU policies – with the Farm to Fork Strategy, a component of the European Green Deal – are targeting sustainable production, including the expansion of organic production (Stojanovic, 2021; OECD, 2022). In this scenario and given the promising health and environmental benefits of organic products compared to conventional agriculture (Schader et al., 2015; Mie et al., 2017), organic food is one of the most popular food categories that has increased its market share over the last 30 years in Western countries. In addition, over the last three decades, extensive research has focused on investigating consumer preferences for organic food (Rödiger & Hamm, 2015; Asioli et al., 2017; Katt & Meixner, 2020). However, consumer research for food products is traditionally conducted using survey questionnaires and/or experiments that use self-reported measures (explicit evaluations). These measurements can lead to an attitude-behavior gap (Lagast et al., 2017; Wörfel, 2021) as they are subject to personal and internalized biasing factors (Danner et al., 2014;

* Corresponding author. Via Volturno 39/E, 43125, Parma, Italy.
E-mail address: mariaalessandra.umilta@unipr.it (M.A. Umiltà).

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De Wijk et al., 2012). To address the need to reduce the gap between consumers' stated and actual behaviors, interdisciplinary research has become of critical interest. For instance, the use of implicit measures, particularly from a physiological perspective (Lagast et al., 2017), could allow for the exploration of unconscious, and often automatic, expressions of those higher cognitive processes that are integrated with the perceptual ones (Coricelli et al., 2019; White et al., 2020; De Wijk & Noldus, 2021). Thus, despite consumer surveys being easy to use, more cost-effective, and simpler to implement, combining them with implicit methods could lead to more precise predictions of consumer food choices (Schouteten, 2021).

Among the different types of implicit measures, the methodologies that integrate bio-signal (e.g. electrocardiogram (ECG) signal, electrodermal activity (EDA) signal, etc.) evaluation during eating behaviors provide great help to marketers to deeper understand "how" and "why" consumers' make their food choices (Cherubino et al., 2019). Indeed, consumers' choices can be revealed through the analysis of their spontaneous approaches and anticipatory behaviors. Among the different implicit methods, physiological techniques, including surface electromyography and movement analysis allow the measurement of transitive behaviors toward objects in an implicit, non-invasive way, and with negligible impacts on spontaneity (Fridlund & Cacioppo, 1986; Gentilucci et al., 1997). For this reason, they can be considered two elective techniques in the implicit measurement of consumers' behaviors and choices. Even though movement analysis and surface electromyography have been utilized in the past to study behavior toward foods (Rustagi, 2020; Sato et al., 2020), to the best of the authors' knowledge, no previous research has used these methodologies to investigate consumer preferences for organically labeled food products.

This manuscript investigates - for the first time - whether labeling a food product (pear juice) as organic could bias consumers' hedonic evaluation and approach behaviors (i.e., movement patterns aimed at achieving a salient object). Our study employs an innovative, multidisciplinary approach by combining explicit responses on the expected and actual degree of liking and implicit measures by recording the electromyographic activity of the mylohyoid muscle (MM) before and during the approaching to and swallowing of pear juice. The MM was chosen because its activity is involved in swallowing anticipation and execution (Brodsky et al., 2012; Cattaneo et al., 2007; Ding, 2003; Leopold & Kagel, 1983). In addition, we recorded the kinematics of the participants' dominant hand during the reaching and grasping movements. Given these premises, we hypothesized that consumers' perception of the organic label might modulate liking evaluations and activation of the MM during the anticipatory phase, before the proper ingestion. In addition, we hypothesized that differently labeled items (organic *vs* non-organic) would elicit distinct rates of readiness and targeted motions during the reaching and grasping phase. Furthermore, we advanced a correlation between the MM activation and reaching/grasping kinematic parameters during movements, aiming to investigate the mouth-hand interaction.

2. Methods

2.1. Surface electromyography

Surface electromyography (EMG) is a non-invasive technique used to measure and record the electrical activity of muscles near the surface of the skin. Specifically, EMG involves placing electrodes on the skin overlying the muscles of interest to detect the electrical signals generated by muscle overt and covert contractions (Fridlund & Cacioppo, 1986). EMG provides valuable information about muscle function and activity patterns and can be used in various applications, including biomechanics, sports science, and rehabilitation (Norali, Som& Kangar-Arau, 2009). Previous studies applied EMG to investigate consumer ingestion behaviors like swallowing (Nicholls et al., 2022). Swallowing has always been considered a reflexive event, necessary only during the act of proper ingestion (Dodds, 1989; Miller, 1972). However, it has been suggested that the swallowing process requires more consumer cognitive involvement that precedes food ingestion as a preparatory phase (Sato et al., 2020). Such a preparatory phase requires precise cognitive resources, including also decision-making and precise motor control for actions (Brodsky et al., 2012; Cattaneo et al., 2007; Leopold & Kagel, 1983). Cattaneo et al. (2007) demonstrated that participants had a pre-activation of the swallowing muscles already during a preparatory phase before the hand reached for the food, and not only during the actual swallowing. However, the authors have not focused on the modulation of this anticipatory muscular activation depending on participants' inclination to consume the food.

2.2. Kinematics

3D Kinematic of the body movements refers to the analysis and measurement of human body movements in three-dimensional space. It involves capturing and quantifying the various aspects of motion, such as position, velocity, and acceleration, of body segments or joints as they move through space. This analysis is often performed using specialized motion capture systems (MOCAP) that tracks the movement of markers placed on the body. This analysis has been applied to obtain a quantitative measure of human movement in response to environmental changes, from the extrinsic properties of the space to the intrinsic properties of the objects toward which we interact. The timewise assessment of hand kinematics during a motor sequence of reaching and grasping, which precedes the bringing a piece of food to the mouth, can provide information about the perturbation of movement landmarks related to motor planning and control (Flindall et al., 2015), which can be influenced by top-down (e.g. high cognitive processes and prior experience altering perceptual process information) and bottom-up (e.g. the perceptual process of the proper characteristics of a stimulus occurs through sensory channels) processes. Due to associating context and previous research (Gentilucci & Gangitano, 1998; Ardón et al., 2019; Glover et al., 2004), it has been demonstrated that not only an object's physical feature but also semantic classifications might activate affordances, which are object properties that suggest the appropriate actions to interact with it (Roda-Sales et al., 2019). The access to specific valence and meanings could activate motor tendencies of approach or avoidance behaviors that interfere with the grasping of target objects (Saraiva, Schüür & Bestmann, 2013; Dings, 2018). Food preferences, for example, systematically influence approach/avoidance tendencies and respective motor actions, which have important implications for eating behaviors (Brunyé et al., 2013; Förster, 2003). Parma et al. (2014) found that consumers reached for a specific food item faster when their liking for the food item itself guided the choice selection. These results indicate that kinematic measures may reflect implicit preferences in the food selection process (Parma et al., 2014).

2.3. Participants recruitment

Participants were recruited using an online survey (administered via Google Forms) spread through word of mouth and social media channels among consumers living in Parma, Italy, in spring 2022. To take part in the study, respondents had to be 18 years or older, be "Always" or "Sometimes" responsible for household food shopping, and purchase and consumer fruit juice at least once every three months. One attention check question was also included in the survey to ensure high-quality data (Berinsky, Margolis & Sances, 2014; Kung, Kwak & Brown, 2018).

Eligible respondents were then asked questions about their sociodemographic (i.e., gender, age, diet, education level, economic status, weight, and height) and consumption and purchasing frequency of organic and regular juice from 1 ("once every three months") to 9 ("every day"). Attitudinal questions were also asked using the organic product scale ("I always buy organic food products If there is a chance", "I make a point of using natural and ecological food products", and "I do not mind paying a higher price for environmentally friendly products") of the FRL-Food-Related Lifestyle (Grunert et al., 2011). This scale was used to obtain a balanced sample based on consumers' attitudes toward organic food products.

Then, eligible participants were contacted by email and invited to take part in the second phase of the study. We instructed participants not to consume any fruit juice on the day of the experiment and to avoid drinking any liquids 1 h before the experiment started. Before the study began, all participants provided written informed consent. Research have been performed in accordance with the Declaration of Helsinki and have been approved by the local University Research Ethics Board (Protocol number: 9294).

2.4. The sample

An a priori power analysis was conducted using G*Power 3.1 prior to data collection. This analysis, assuming a repeated-measures ANOVA with a within-subject factor as the primary method of analysis, was based on an expected medium effect size ($f = 0.25$), an alpha level of 0.05, and a desired power of 0.80. The analysis determined that a sample size of 28 participants would be necessary to detect significant effects.

To meet this requirement, we initially recruited 33 participants for the study. All participants provided informed consent, and those who completed both steps of the study were rewarded with a small perk as a token of appreciation for their participation. However, four participants were excluded from the analyses: two had more than 30% of trials rejected for EMG artifacts, and two resulted as outliers in the kinematics analysis. The final sample included 29 participants who tend to be younger (mean age 26.59 years) and females 22 out of 29. The socio-demographic characteristics of the sample used for the analyses ($n = 29$) are represented in Table 1.

Table 1
Sociodemographic characteristics of the sample ($n = 29$).

Sample characteristics		N	%
Gender			
	Female	22	76%
	Male	7	24%
Age (years)			
	18–35	26	89%
	36–50	2	7%
	51–65	1	4%
Diet			
	Omnivore	21	72%
	Flexitarian	7	24%
	Vegetarian	1	4%
Highest education level			
	High school	12	41%
	Bachelor's degree	12	41%
	Master's degree	4	14%
	PhD	1	4%
Economic status			
	Very poor	0	0%
	Quite poor	4	14%
	Moderately poor	4	14%
	Neither poor nor rich	10	34%
	Moderately rich	8	28%
	Quite rich	3	10%
	Very rich	0	0%
BMI			
	Underweight	4	14%
	Normal weight	20	69%
	Overweight	5	17%
FRL			
	Low level	13	45%
	High level	16	55%
Juice consumption frequency			
	Less than once a month	3	10%
	1-4 times a week	22	76%
	Daily or almost daily	4	14%
Organic juice consumption frequency			
	Less than once a month	18	62%
	1-4 times a week	11	38%
	Daily or almost daily	0	0%
Juice purchasing frequency			
	Less than once a month	5	17%
	1-4 times a week	24	83%
	Daily or almost daily	0	0%
Organic juice purchasing frequency			
	Less than once a month	18	62%
	1-4 times a week	11	38%
	Daily or almost daily	0	0%

Note: FRL questions are based on a 7-point Likert scale; thus, respondents were divided into individuals with a low- (average score <4) or high-interest level in organic food (average score >4).

2.5. Lab experiment

2.5.1. Explicit measurements

Upon their arrival at the Kinematic Laboratory of the Unit of Neuroscience of the Department of Medicine and Surgery (DIMEC) of the University of Parma (Italy), each participant was randomly presented with two dark glass bottles of pear juices, with and without the organic label. A non-transparent packaging was chosen to avoid consumers being affected by the product's color. Based on the study design of other works (e.g., Lee et al., 2013; Sörqvist et al., 2013; Schouteten et al., 2019), apart from the packaging, the two products were identical but presented using two different labels ("pear juice" and "organic pear juice"). We chose pear fruit juice because it is the most consumed fruit juice in Italy (Ansa, 2019; Misuraca, 2019). The pear juice used was always the same under any experimental condition and was produced by an Italian supermarket (i.e., CONAD).

Explicit measures were divided into two temporally distinct phases. The first phase occurred prior to the actual experiment and involved assessing the 'expected liking' based solely on the labels ("pear juice" and "organic pear juice") of the juice bottles, without tasting the contents. In the second phase, after the implicit data acquisition, participants tasted the contents of the two bottles with different labels and then evaluated their actual liking for each. Throughout both phases of explicit assessment, participants responded via the Qualtrics platform, utilizing a scoring scale ranging from 1 (dislike extremely) to 9 (like extremely; Peryam & David, 1957). In both the expected and actual liking phases, the two bottles of juice, each labeled differently, were randomly presented.

2.5.2. Implicit measurements

The experimental protocol was composed of 60 trials, 20 for each condition: organic fruit juice (ORG), non-organic fruit juice (NO-ORG) and water (H_2O). Across the trials, the experimental conditions were randomized and balanced. During each trial, participants were asked to follow specific prerecorded audio instructions to reach, grasp and then sip from the glass bottle located in front of them. Fig. 1 represents a graphical, detailed description of the trial events structure. The use of audio instructions ensured consistency and uniformity among participants regarding the motor events constituting the trial. The onset and the offset of each motor event were measured using a touch-sensitive circuit board. The starting and the end positions of participants' hands were standardized (i.e., pinching position). Lastly, to avoid participants' anticipatory reactions, they were asked to keep their eyes closed during the inter-trial interval (ITI). Each trial included a premovement component with a fixed duration of 21 s, consisting of the following phases: Inter-trial (15 s), visual anticipation (3 s), and motor anticipation (3 s). The motor phase of the trial had a variable duration (between 1 and 2 s), depending on each participant's movement execution speed in relation to the experimental conditions.

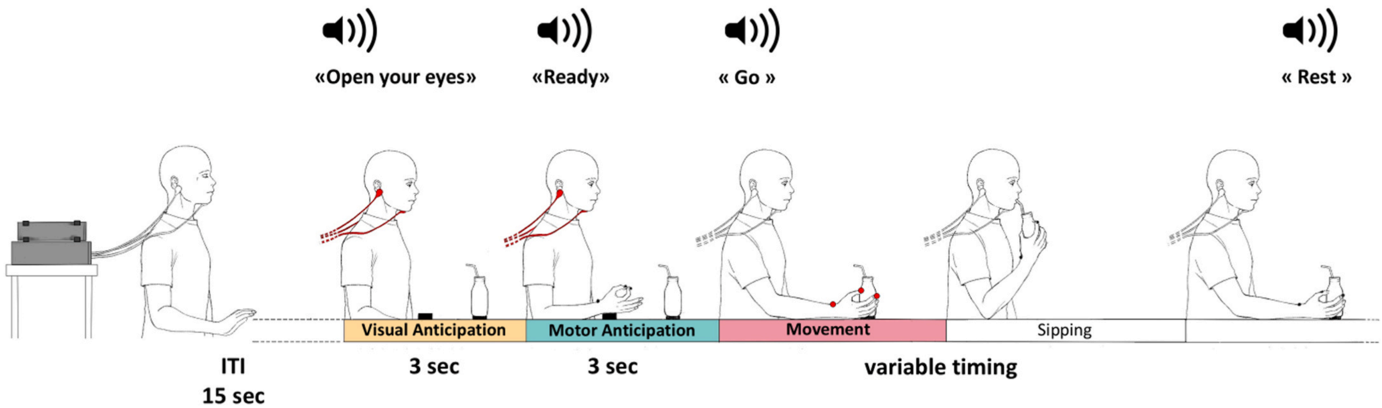

Fig. 1. Succession of the events in a single trial.
Note: Interval inter-trial (**ITI**) = time lapse between trials; **visual anticipation** (highlighted in yellow) = after the command "Open your eyes" participants were asked to observe the bottle and MM (electrodes in red) was recorded; **motor anticipation** (highlighted in light blue) = after the command of "Ready" participants put their hand in the starting position and MM (electrodes in red) was recorded; **movement phase** (highlighted in pink) = after the command of "Go" participants grabbed the bottle and hand movement was recorded (markers in red). They subsequently brought the bottle to their lips, took a sip of the contents (**sipping**) and returned the bottle to its position.

Before the experimental session, EMG electrodes and kinematics markers were placed under the participant's chin and right hand to measure their spontaneous muscular activation and reaching movements, respectively. During the entire experimental procedure participants' Mylohyoid EMG activity and arm and hand movements were recorded.

To uniform visual sensory information across conditions, we used 200 ml capacity glass bottles wholly painted with electrically conductive opaque paint. Each experimental condition was communicated to the participants through a label attached to the straw inserted into the bottle, which they used to consume the contents. The same pear juice was used between the organic and non-organic juices condition. Refer to Fig. 2 for a visual representation of the three experimental conditions.

Participants sat comfortably at a table (80 cm × 60 cm x 115 cm), where they interacted with the touch-sensitive circuit board (with dimensions 50 cm × 40 cm) throughout the experiment (see Fig. 3). They were asked to place their right hand in a pinching position on a flat rectangular touch-sensitive platform. This was the starting position and was aligned with the participant's mid-sagittal plane. The participant's hand was 30 cm away from the circular touch-sensitive platform where the target bottle was located. Both platforms were covered with graphite and connected with copper cables to the board (Makey Makey®), which communicated directly with the computer from which voice commands were sent. The use of bottles coated with electroconductive paint allowed effective interaction with the circuit board since this setup allowed signals indicating when participants lifted and returned the bottle to its original position; these signals were sent to and recorded by the computer.

Mylohyoid EMG activity was bipolarly recorded under the participants' chin with 4 mm standard Ag/Ag-Cl electrodes. Before being attached to the MM region, the electrodes were filled with gel electrode paste and the participants' skin was cleaned with an alcohol solution (Fridlund & Cacioppo, 1986; Van Boxtel, 2001). EMG data were converted and amplified with an eight-channel amplifier (PowerLab8/30; ADInstruments UK) and displayed, stored, and reduced with LabChart 7.3.1 software package (ADInstruments , 2011). Mylohyoid EMG was sampled at 2 kHz and recorded with an online Mains Filter (adaptive 50 Hz filter). A 25–500 Hz band-pass filter (Van Boxtel, 2001) was applied offline on the raw mylohyoid EMG signal. The EMG amplifier was positioned behind the participant's back (see Fig. 3).

The reach-to-grasp and lift motor sequences performed by the participants were recorded using a marker-based 3D optoelectronic system (SMART; BTS Bioengineering). As described in Fig. 3, this system included six infrared cameras (surrounding the table at which the participant was seated) that tracked the position of three reflective spherical markers at a sampling rate of 120 Hz and with a spatial resolution of 0.3 mm. Two smaller reflective markers (5 mm in diameter) were attached to the participants' right thumb and index fingernails (grasping markers). A third marker (10 mm in diameter) was placed on the wrist (reaching marker).

Fig. 2. From trial to trial, the three experimental conditions were shown in a randomized order.
Note: The three conditions H_2O, **ORG**, and **NO-ORG** were shown on the bottle labels. In order to simplify the figure only one camera is shown but the experimental setting included 6 cameras.

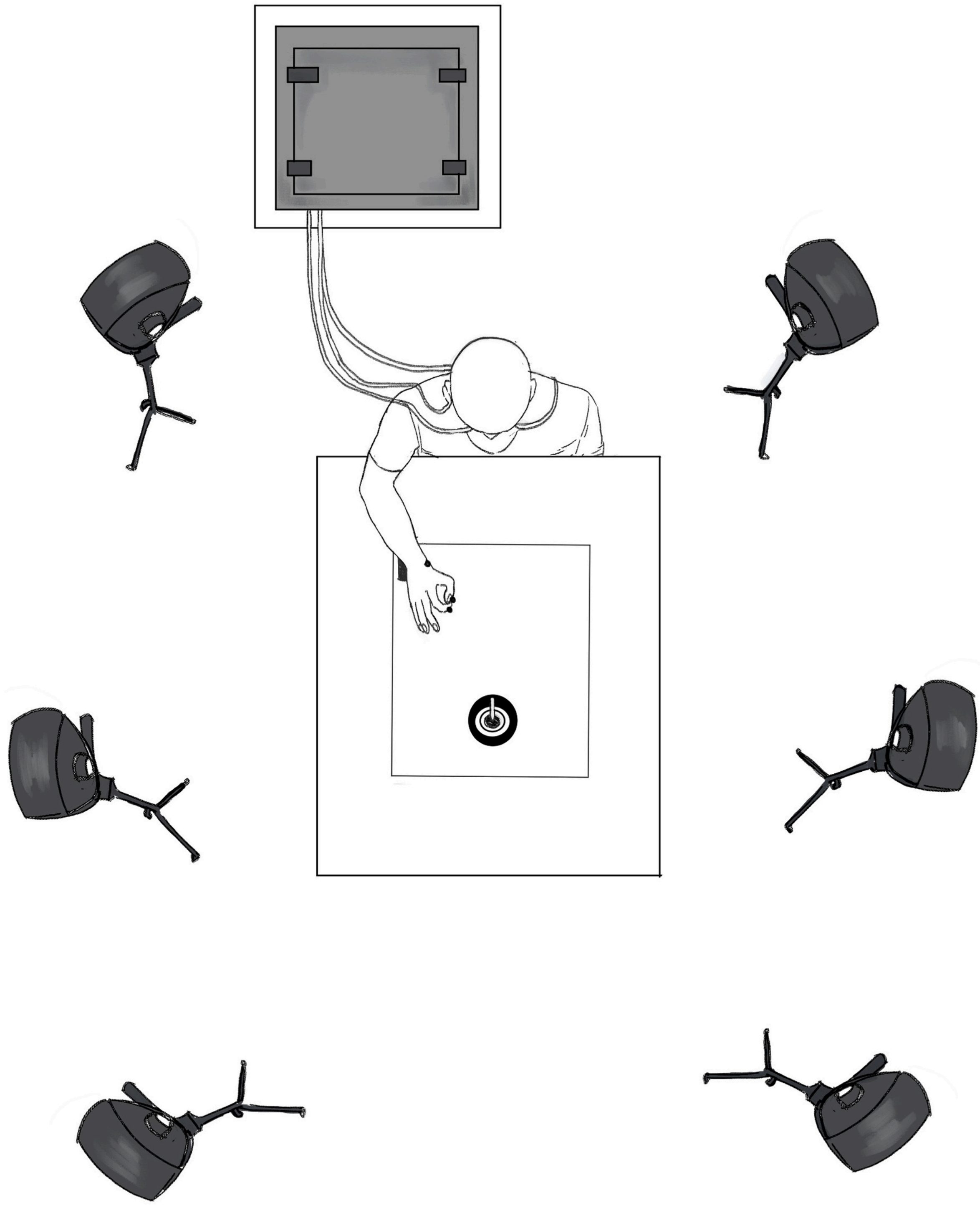

Fig. 3. Experimental setting: the two touch-sensitive circuit boards (hand starting position, rectangular board; bottle position, circular board), an eight-channel amplifier (PowerLab8/30), and a 6-camera marker-based 3D optoelectronic system (SMART).

Fig. 3 shows the overall experimental setting. See also Figs. 1 and 2 Supplementary Material.

Finally, at the end of the lab experiment, all participants were then fully debriefed about the deception used in the study before leaving the session. Specifically, participants were initially led to believe they were consuming both an organic and a non-organic juice during the experiment. In reality, they were given the same juice throughout. At the conclusion of the study, participants were informed that they had actually been drinking the same juice, with only the labels creating the illusion of different products.

3. Data analysis

Data analysis was performed in several steps.

First, explicit measures using the consumers' degree of liking were analyzed using a 2x2 analysis of variance (ANOVA) to investigate the differences between expected *vs.* actual liking and labeling (organic vs. non-organic juice). Post-hoc comparisons were conducted using Tukey's correction for multiple comparisons.

Second, the implicit measures using EMG, following the standard practice (Lang et al., 1993; Winkielman & Cacioppo, 2001), the average of the absolute value of the EMG signal in a window of 500 msec was computed. EMG response (millivolts) was measured as change scores representing the difference between the activity of each 500 msec epoch and the MM mean amplitude of the 500 msec right before the beginning of each trial (baseline epoch). EMG signal and video recordings were visually inspected off-line by the experimenters. To remove artifacts, EMG data about the participants' contingent movements (e.g., coughing, talking or whole head movements) were excluded from the analysis. Moreover, trials with mean change scores that were 2 SD above or below the grand mean change score calculated for each participant were considered outliers and removed. Based on these criteria, EMG analysis was conducted on 29 individuals. Based on the trial structure, we identified two main events called visual anticipation (see Fig. 1, *Yellow*) and motor anticipation (see Fig. 1, *Light Blue*), both phases divided into 6 epochs of 500 ms each. Visual anticipation corresponds to the EMG responses detectable during the observation of the target bottle when participants were instructed to read the label but before planning any movement. In contrast, motor anticipation relates to the EMG responses measurable when participants were instructed to prepare for the reaching-to-grasp action while still awaiting the go signal. These two events were chosen for the EMG analysis because they identify potential preparatory muscular activations triggered by visual or motor information, respectively.

To examine whether the mylohyoid muscle activity was influenced by experimental conditions, two linear mixed-effect analyses were conducted separately for visual and motor anticipation events. Employing a hierarchical approach, we initiated a straightforward model comprising a single parameter and gradually incorporated additional elements to assess their impact on model fit. The dependent variable was the participants' mean activation of the mylohyoid muscle, and the independent fixed variables were the experimental conditions (ORG, NO-ORG, H_2O) and EMG epochs (six levels). Participants were included as a random intercept, while experimental conditions and EMG epochs were treated as random slopes. This approach accommodated within-subject data variability. Outliers were detected and excluded from the analysis based on standardized model residuals and a Cook's distance threshold of 1. Post-hoc comparisons were conducted using Tukey's correction for multiple comparisons.

Third, the analysis of kinematics data. During the execution of reach-to-grasp (see Fig. 1, *Pink*), we recorded participants' kinematics for 4 s from the "GO signal" capturing both the grasping and reaching phases. Displacements, velocities, and accelerations of the reach and grasp movements were analyzed. We measured the grasp component by analyzing the time course of the distance between the thumb and the index finger and the following kinematics landmarks: maximal grip aperture, grasp aperture peak velocity, grasp aperture peak acceleration, and grasp aperture duration with respect to the entire grasping movement. To study the reach component, which is constituted by an ascendent and descendent phase intercut with the point of maximal elevation, we analyzed the following kinematics parameters: reach peak velocity, reach peak acceleration, reach peak deceleration and the maximum curvature of the reaching movement. These reaching and grasping parameters were calculated to assess the effects on the initial and central part of the reach-to-grasp action, which are influenced by planning and execution control (Jeannerod, 1988; De Stefani et al., 2016).

Recorded data were extracted and pre-processed using homemade functions developed using MATLAB (R2015a). A Gaussian low-pass smoothing filter (sigma value: 0.93) was applied to the recorded data (De Stefani et al., 2016).

Regarding kinematics data, linear mixed models were carried out for each dependent variable (maximal grip aperture, peak velocity of grip aperture, peak acceleration of grip aperture, the percentage of the duration of the grip aperture, peak acceleration, peak velocity, peak deceleration and the maximum curvature of the reaching movement), with experimental conditions (ORG, NO-ORG, H_2O) as the independent fixed variable. Participants were included as a random intercept. Also, in this case, the model accounted for the within-subject variability. Outliers were identified and excluded from the analysis based on the standardized model residuals and a threshold value of Cook's distance (threshold = 1, commonly used cut-off in statistical practice). Post-hoc tests were conducted using Tukey's correction for multiple comparisons.

Correlations between MM average activation in the movement phase (see Fig. 1, *Pink*) and kinematic parameters were estimated using Spearman's correlation analyses.

Statistical analyses were performed using R software (R Core Team, 2022), lme4 (Bates et al., 2014), emmeans (Lenth, 2021), effectsize (Ben-Shachar et al., 2020), MuMIN (Barton, 2009) packages. For data plotting, we used the ggplot2 (Wickham & Wickham, 2016) package.

4. Results

4.1. Explicit measures: consumers' degree of liking

The ANOVA model shows only a significant main effect of the labeling ($F_{(1,28)} = 12.89$, $p < 0.01$, $\eta_p^2 = 0.32$) which reveals that participants prefer the organic-labeled juice (mean [M] = 7.60, standard error [SE] = 0.15) over the non-organic-labeled juices (M = 7.05, SE = 0.15). Fig. 4 graphically shows the results for consumers' liking scores for the labels main effect.

4.2. Implicit measures: EMG results

The model performed on the Visual Anticipation phase explained 49% of the variance in the dependent variable considering the random effects ($R_c^2 = 0.49$). Table 2A indicates that he the model showed a main effect of Epochs ($F_{(5,133)} = 9.66$, $p < 0.01$, $\eta_p^2 = 0.27$). Post-hoc analyses revealed that the EMG activity recorded during the first epoch (M = 1.10, SE = 0.17) was significantly higher than all the others, except for the last one (all $p_s < 0.01$; Epoch 2 (M = 0.09, SE = 0.18), Epoch 3 (M = −0.09, SE = 0.18), and Epoch 4 (M = 0.22, SE = 0.18), Epoch 5 (M = 0.26, SE = 0.18)). Indeed, Epoch 6 (M = 0.60, SE = 0.18) resulted significantly higher than Epoch 3 alone ($p < 0.01$).

Table 2B shows the Motor Anticipation phase and the model explained 72% of the variance in the dependent variable considering the random effects ($R_c^2 = 0.72$). The model revealed a significant main effect of condition ($F_{(2,56)} = 3.30$, $p = 0.04$, $\eta_p^2 = 0.11$), which showed a higher MM average activation when participants were waiting to grasp the

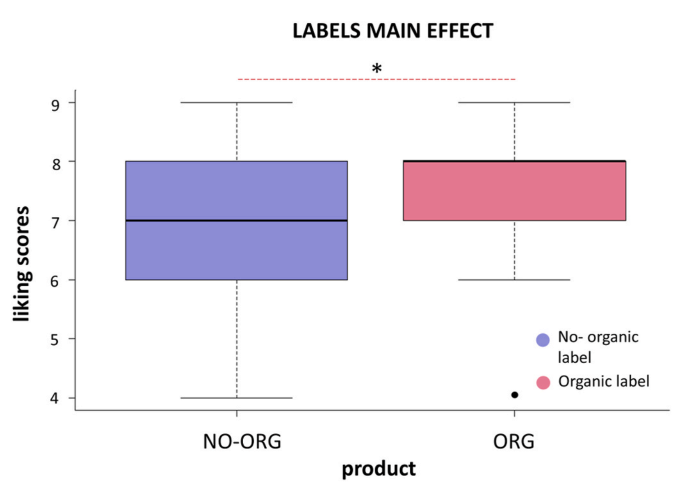

Fig. 4. Participants' degree of liking for the non-organic- (NO-ORG) and organic-labeled (ORG) pear juice from 1 (dislike extremely) to 9 (like extremely).
Note: The bold line represents the median value. The vertical whiskers indicate the minimum and the maximum value.

Table 2A
EMG activation during Visual Anticipation.

		Linear Mixed Model analysis on Visual Anticipation			
Index	Main Effect	F	p	post-hoc	$p_{post\text{-}hoc}$
MM activation mV	Epochs	F(5,133) = 9.66	<0.001	Epoch 1 > Epoch 2–5 Epoch 6 > Epoch 3	<0.001 0.008

bottle with the organic label (M = 1.81 mV, SE = 0.41) than the one labeled as water (M = 0.74 mV, SE = 0.41, p = 0.03). The model also revealed a significant main effect of the factor Epochs ($F_{(5,140)} = 3.42$, $p < 0.01$, $\eta_p^2 = 0.11$), which shows a modulation along epochs from the minimum (Epoch 2; M = 0.42 mV, SE = 0.43, p < 0.01) to the maximum (Epoch 5; M = 2.05 mV, SE = 0.43) of the range of the MM average activation. Interestingly, the model revealed a significant Condition*Epochs interaction ($F_{(10,280)} = 3.03$, $p < 0.01$, $\eta_p^2 = 0.10$, see Fig. 5) and post-hoc comparisons showed a modulation of the MM activation in favor of the organic label along epochs. Specifically, in Epoch 1, there was a higher MM activation while participants were awaiting the bottle with the non-organic label (M = 2.12 mV SE = 0.54) than the one labeled H_2O (M = 0.13 mV, SE = 0.54, p < 0.01). Subsequently, in Epoch 3 this difference moved toward the bottle labeled as organic (M = 1.94 mV, SE = 0.54) when compared to H_2O (M = 0.42 mV, SE = 0.54, p = 0.02). Finally, participants showed a higher MM activation while waiting to grasp the bottle with the organic label (M = 2.93 mV, SE = 0.54) compared to the non-organic label (M = 1.36 mV, SE = 0.54, p = 0.01). Fig. 5 presents a graphical representation of the MM amplitude in significant Condition*Epochs interaction.

4.3. Implicit measures: kinematics

The linear mixed models performed revealed a significant main effect of the condition in six kinematics variables compared to the eight analyzed.

As shown in Table 3 and in Fig. 6a, the model performed on the reaction time – e.g., when the reaching movement begins – showed a significant difference between the onset of the movement towards the non-organic-labeled bottle (M = 109.40 ms, SE = 2.29) and the onset towards the organic-labeled one (M = 107.50 ms, SE = 2.29, p = 0.03). This result shows that our participants started the reaching movement earlier and, therefore, were faster when reaching the organic-labeled bottle. The peak velocity model demonstrated that participants reached for the H_2O bottle faster (M = 674.85 mm/s, SE = 18.32) compared to the organic (M = 660.06 mm/s, SE = 18.32, p < 0.01) and the non-organic-labeled bottle (M = 663.5 mm/s, SE = 18.32, p < 0.01). The model performed on the peak deceleration of the reaching variable revealed a higher peak during reaching H_2O (M = 3353.97 mm/s^2, SE = 177.29) than for reaching the bottles labeled as organic (M = 3205.18 mm/s^2, SE = 177.28, p < 0.01) and non-organic (M = 3253.03 mm/s^2, SE = 177.29, p = 0.04). This can be translated as a more rapid reduction

Table 2B
EMG activation during Motor Anticipation.

		Linear Mixed Model analysis on Motor Anticipation			
Index	Main Effect	F	p	post-hoc	$p_{post\text{-}hoc}$
MM activation mV	Condition	F(2,56) = 3.30	0.04	ORG > H2O	0.03
	Epochs	F(5,140) = 3.42	<0.001	Epoch 2 < Epoch 5	<0.001
	Condition*Epochs	F(10,280) = 3.03	<0.001	NO-ORG Epoch 1 > H2O Epoch 1 ORG Epoch 3 > H2O Epoch 3 ORG Epoch 5 > NO-ORG Epoch 5	<0.001 0.02 0.01

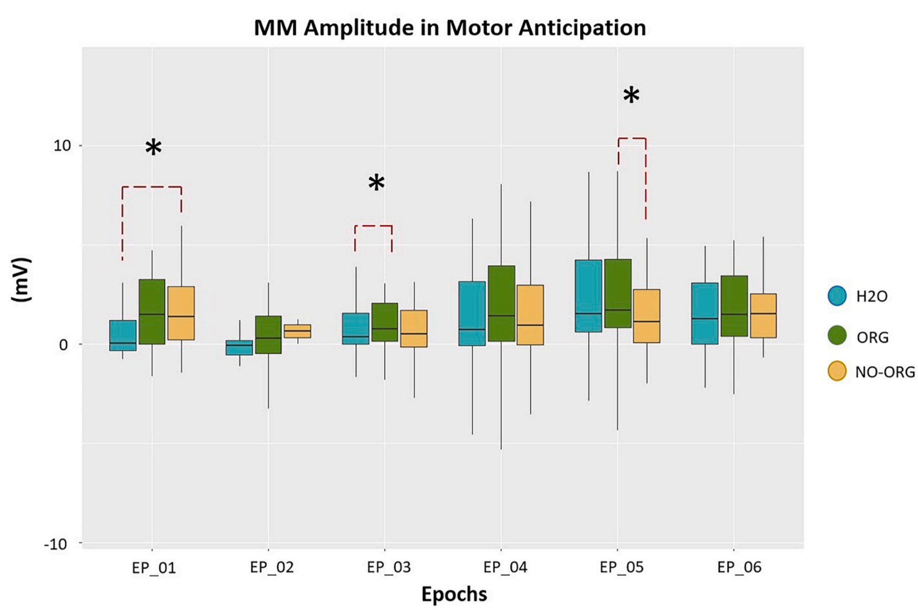

Fig. 5. MM amplitude in Condition*Epochs interaction. Note: The bold line represents the median value; the vertical whiskers indicate the minimum and the maximum value; * = p < 0.05. H2O = water; ORG = organic-labeled product; NO-ORG = non-organic-labeled product.

Table 3
Linear mixed model analysis kinematics results.

		Linear Mixed Model analysis			
Movement	Index	$F_{(2, 1691)}$	p-value	post-hoc	p post-hoc
Main Effect Condition	Reaction Time ms	3.18	0.041	NO-ORG > ORG	0.03
	Reach Peak Velocity mm/s	8.77	<0.001	H2O > ORG	<0.001
				H2O > NO-ORG	0.004
	Reach Peak Acceleration mm/s^2	0.07	0.92		
	Reach Peak Deceleration mm/s^2	6.48	0.002	H2O > ORG	0.001
				H2O > NO-ORG	0.04
	Reach Maximal Curvature mm	6.31	0.002	ORG > H2O	0.01
				NO-ORG > H2O	0.003
	Maximal Grip Aperture mm	0.89	0.41		
	Grasp Aperture Peak Velocity mm/s	3.99	0.019	ORG > H2O	0.01
	Grasp Aperture Peak Acceleration mm/s^2	8.45	<0.001	ORG > H2O	<0.001
				NO-ORG > H2O	0.02
	Grasp Aperture Duration % of total movement	3.08	0.04	H2O > NO-ORG	0.04

in speed when participants reached the water in comparison to both juices. Lastly, the maximum curvature of the reaching movement showed that participants were making a much larger reaching movement with greater curvature both going toward the organic (M = 21.26 mm, SE = 3.15, p = 0.01) and non-organic juice (M = 21.51 mm, SE = 3.15, p < 0.01) compared to H2O (M = 19.35 mm, SE = 3.15).

In terms of grasp component variables, as shown in Fig. 6b, the model performed on the grasp aperture peak velocity showed a significant difference between the opening speed in the organic condition (M = 368.62 mm/s, SE = 16.82) compared with the H_2O condition (M = 352.57 mm/s, SE = 16.83, p = 0.01). This shows that participants were opening their hand faster to grab the organic-labeled juice. The model performed on the peak acceleration of the grip aperture variable revealed a higher acceleration toward the juice labeled as organic (M = 6958.34 mm/s^2, SE = 438.08) compared with H_2O (M = 6273.42 mm/s^2, SE = 438.14, p < 0.01). Furthermore, a higher acceleration toward the juice labeled as non-organic was found (M = 6747.36 mm/s^2, SE = 16.82) compared with H_2O (M = 6273.42 mm/s^2, SE = 438.14, p = 0.02). The last statistically significant grasping parameter was the percentage of the duration of the grip aperture. This value was greater during grasping H_2O (M = 63.52% of total movement, SE = 1.22) than during grasping the bottle labeled as non-organic (M = 62.42% of total movement, SE = 1.22, p = 0.04).

4.4. *Correlations between MM activation and kinematics parameters*

Fig. 7 shows the correlation between MM activation and kinematics parameters. After correction for multiple comparisons with Holm adjustment, a significant positive correlation was found between participants' MM average activity in the Movement phase (see Fig. 7 left panel) and the grasp aperture duration ($r_{(73)} = 0.31$; p = 0.04). Additionally, a significant negative correlation was found between participants' MM average activity in the Movement phase (see Fig. 7 right panel) and the reach maximal curvature ($r_{(73)} = -0.64$; p < 0.01).

5. Discussion

This study introduces an innovative method by combining consumer valuation with physiological measures to explore the implicit aspects of organic food preference. Our results indicate that muscular activation was observed when participants viewed the organic-labeled juice, suggesting a targeted preparatory motor response. Moreover, analyses of arm and hand movements revealed shorter reaction times and more selective grasping actions when reaching for the organic-labeled juice compared to the non-organic-labeled counterpart. Additionally, the presence of the organic label significantly impacted the degree of liking among consumers.

The results of the study confirmed our hypotheses by suggesting

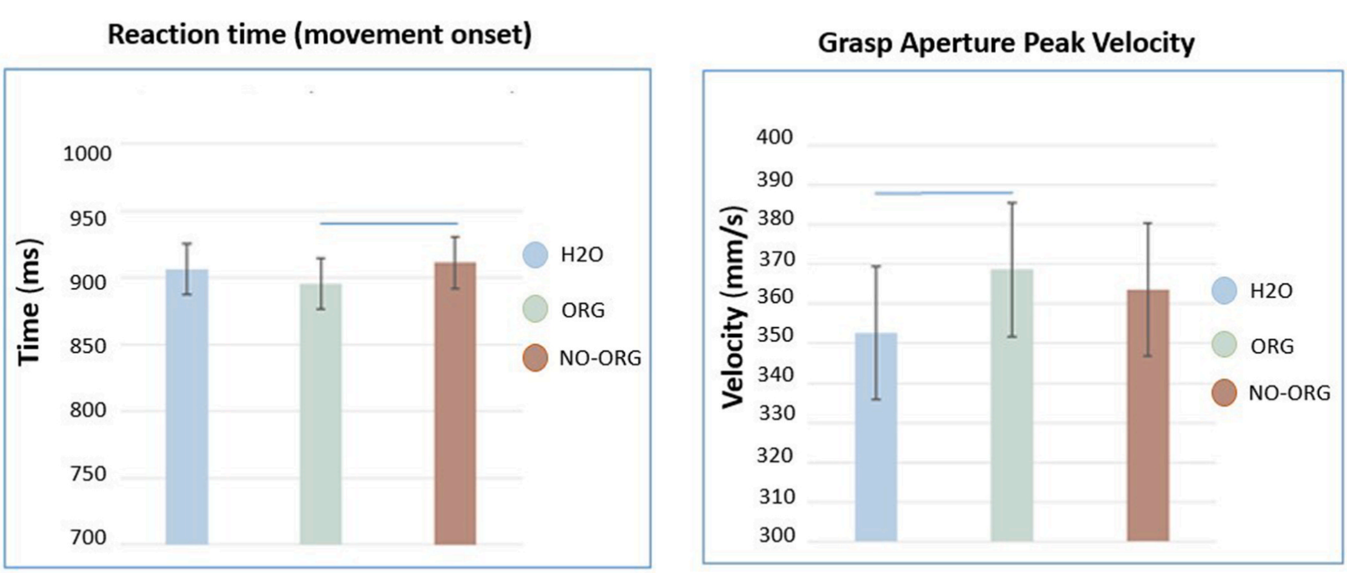

Fig. 6. Significant post-hoc results in a) movement onset parameter (start of reaching movement) and b) peak velocity parameter during the grip aperture. Note: Horizontal lines = p < 0.05. H2O = water; ORG = organic-labeled bottle; NO-ORG = non-organic-labeled bottle.

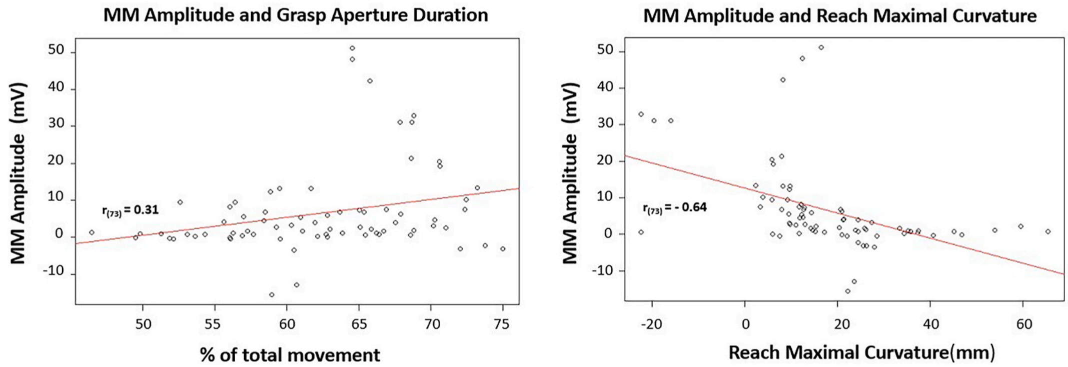

Fig. 7. Significant correlations between the MM amplitude and both grasp aperture duration (left) and reach maximal curvature (right).

distinct motor patterns associated with each label type, which demonstrates the impact of food labels leading up to the swallowing process. Our findings shed light on the subtle yet profound ways in which food labels can shape our food-related behaviors, in particular in the context of organic consumption. Specifically, we found several interesting results. First, we found that consumers have a preference for organic-labeled goods rather than non-organic-labeled ones. Second, we found that there is a pre-activation of the MM in the motor anticipation phase during the organic-labeled juice presentation. Third, we found that reaching movement began with shorter reaction times in the organic condition when compared to the non-organic condition. Fourth, we showed that participants exhibited a faster closing movement of their hand during the grasping of the organic-labeled juice compared to the non-organic-labeled juice. Fifth, participants who showed higher MM activity during the movement phase tended to have longer grasp aperture durations and lower reach maximal curvature. The consistent differences observed in consumer degree of liking, MM activation, reaching trajectories, and grasping movements across label conditions highlight the widespread impact of food labels on food-related actions.

These findings collectively support the Label-Feedback Hypothesis (LFP) (Lupyan, 2012), which proposes that labels can shape sensory experiences and influence consumer behavior. Food labels act as cues by informing the expectations about the sensory properties and attributes of the food item (Songa et al., 2019). Specifically, our participants expected the organic-labeled juice to be tastier than the non-organic one. These findings are in line with previous research, which showed that consumers' sensory expectations and perceptions are affected by the presence of the organic label (Sörqvist et al., 2013; Apaolaza et al., 2017; Asioli et al., 2018; Schouteten et al., 2019).

Interestingly, participants' different expectations for the organic and non-organic juice found their counterparts in the implicit responses. Our results unveiled a novel relationship between people's explicit statements about a food product and their motor behavior when approaching the same product. Clearly, labeling played a crucial role in linking these two behaviors, aligning participants' reported expressions of their preferences with their actions.

During the visuomotor phase of the task, as participants observed the three bottles (each one displaying a different label) while awaiting the signal to start the movement, significant differences in the activation of the MM were identified. During the initial waiting phase, muscle activation was higher for both juices compared to water, which is likely influenced by the sensory properties of the juice, such as density and sweetness. Our finding, which indicates a greater MM activation for juices during the anticipatory pre-oral phase preceding ingestion, is corroborated by Ko and coworkers (Ko et al., 2021) who demonstrated a stronger pre-reflex phase of muscle activation in response to increased viscosity and an effect of sweet taste on the EMG of submental muscles during the preoral preparation phase (Leow et al., 2007). Selectivity for label semantic valence occurred between 1000 and 500 ms before the Go signal, with the MM activation significantly greater for the organic condition than for the non-organic condition. We suggest that this early activation might correspond to a salivation reflex. Indeed, it is well-known that this process could be induced by seeing or smelling food (Krishna et al., 2014; Wooley & Wooley, 1973), or even by a goal-driven aim (Gal, 2012). This pre-activation follows the concept of the "anticipatory phase," where our neural systems anticipate and get prepared for upcoming actions (Cattaneo et al., 2007; Kober et al., 2015). Participants exhibited a higher MM activity when anticipating reaching for an organically labeled juice bottle compared to a non-organically labeled one. This finding suggests that the association with the organic label triggered anticipatory responses in the swallowing system, potentially reflecting the higher expected liking of participants for the organic-labeled juice. The preference for the organic label persisted in the subsequent response movement. As participants prepared to reach for the food item, their actions were notably influenced by the label: participants exhibited quicker responses when the target was an organically labeled juice bottle, indicating a faster initiation of the approaching movement. This suggests that the specific label facilitates a quicker response to the action cue. These findings are corroborated by previous studies which suggest that initiation times of approaching movements increase when the target is considered salient (Zehetleitner, Hegenloh & Müller, 2011; van Zoest & Kerzel, 2015). The influence of labels extended to the actual reaching movements as well. Participants exhibited more precise and accurate reaching trajectories when aiming for juices compared to water, which indicates heightened attention and focus on juices (Betti, Castiello & Begliomini, 2021). Moreover, the preference for the organic-labeled juice became markedly apparent in the peak velocity of the grip aperture during grasping, with participants opening their hand faster to grasp the organic product. While previous works in the literature demonstrated bottom-up effects of intrinsic sensory characteristics of food (Betti, Castiello & Begliomini, 2021) – such as size (Gentilucci, 2003), smell (Castiello et al., 2006; Tubaldi et al., 2008), and flavor (Parma et al., 2011) – this study is the first to reveal that the content of a label alone, and thus the value given for prior experience and set expectations, has a specific and direct impact on grasping actions. We demonstrated indeed a top-down effect evoked by the semantic content of the label read by participants, which led them to act more quickly toward the product they associated with a positive valence elicited by the presence of the word "organic" (Betti, Castiello & Begliomini, 2021). Furthermore, previous research in both primates and humans has already shown that reaching movements are guided by the dorsomedial frontoparietal areas of the brain, while grasping is controlled by the sensorimotor cortex, which receives sensory information from the hand and fingers and integrates this information with appropriate motor commands (Connolly et al., 2003; Culham et al., 2006; Kaas et al., 2012; Konen et al., 2013; Yttri et al., 2014; Wishaw et al., 2014). These factors allow for a more refined control of the grip and ensure that objects are grasped securely and efficiently. Two kinematic variables were not significant: maximum grip opening and peak acceleration during reaching. In our view, maximum grip opening was not significant because this parameter varies with the size and shape of the object to be gripped, which, in our case, was always the same bottle across all experimental conditions. As for peak acceleration during reaching, one possible explanation is that the total reaching time did not vary sufficiently between conditions, while velocity did—and this difference was indeed significant.

The MM activation and kinematics of arm and hand movements were both directed toward the common goal of tasting the juice. We found that they are part of the hand-mouth motor chain for feeding, as previously shown in other studies (Ferrari et al., 2003; Kiverstein et al., 2019). Participants with a heightened MM activity exhibited more prolonged grasp aperture durations and a reduced reach maximal curvature. A wider grip aperture and faster reaching might necessitate more efficient mouth movements to prepare for incoming food, which indicates a need for high cognitive involvement leading to coordinated and well-planned movements. This aligns with prior observations that showed an initiated mouth opening early in "reaching to eat" tasks (Shune et al., 2016), which highlights the prevalence of the hand-mouth motor chain specifically triggered by the intention to act (Cattaneo et al., 2007). From a motor control perspective, these preparatory actions contribute to task success and facilitate a more efficient process.

We acknowledge that there are further limitations that should be addressed in this study. Specifically, the relatively small sample size, due to the extended time required for data collection, limits the generalizability of our findings to a larger population. Moreover, the sample predominantly consisted of younger participants, which may further restrict the applicability of the findings across different age groups. Future research could benefit from including a more diverse sample to enhance the generalizability of the results to other age groups and populations.

Another limitation concerns the selection of juice as a stimulus, which may restrict the applicability of the results to other types of edible products or broader food categories. While participants were advised not to drink for an hour prior to the experiment to enhance the taste and refreshing qualities of the juice, their hunger or thirst levels were not systematically controlled, which could have influenced their perceptions. Furthermore, although the chosen juice was one of the most popular in Italy, the use of a single type of juice might reduce the ecological validity of the results when considering a wider range of edible products. These factors should be considered when interpreting the results, and future research could benefit from incorporating a broader range of stimuli and more rigorous control of participants' physiological states to ensure broader generalizability across different populations and food categories.

Several suggestions for future research studies can be identified from this study. First, future studies should investigate a larger and more representative consumer sample size. Second, we suggest exploring whether the inclination toward consuming organic products influences the execution of approach movements toward food items. Specifically, future studies should focus on the investigation of whether the motor control exerted by the semantic content of the label is influenced by people's attitudes toward organic food products, the environment, and healthiness. Third, future studies should investigate the relationship between other explicit methods used in economics and marketing sciences (e.g. choice experiments, experimental auction) with other implicit methods, including EEG. Fourth, future research could explore additional food categories (e.g., healthy *vs* non-healthy food) to gain deeper insights into consumer behaviors towards such foods. Such investigations could aid in more effectively nudging consumers towards making better food choices. Finally, it would be interesting to examine whether the findings obtained during the movement execution have a corresponding effect when observing other people implementing these movement approach patterns toward organic-labeled food products.

6. Conclusions

Our results provide novel and interesting insights into participants' implicit behaviors when faced with food products labeled as organic or non-organic. However, it will be valuable in future research to improve the experimental paradigm to specifically investigates the relationship between implicit measurements and consumers' explicit responses.

Although our results pertain specifically to bottled fruit juice, future studies involving food products would be valuable to determine the generalizability of our findings. The results of our study showed for the first time that participants' implicit approach behaviors toward a food product labeled as organic differed from their behaviors toward a non-organic product. In the future, it will be interesting to extend this research by using different types of food products, the design of the containers, adjusting the price on the label, involving participants of different ages, or even conducting gender-based studies. We believe that our findings provide an important starting point for more focused and in-depth studies.

Our study offers compelling evidence that food labels have a significant impact on both motor approach behaviors and reported sensory evaluation toward food items. Choosing what to consume is a fundamental daily task with profound implications for personal well-being and environmental sustainability. Yet, there is often a disparity between consumers' reported intention and their actual behavior, which is influenced by intricate and not-easy-to-understand factors. Our study contributes to exploring the physiological aspects that influence consumers' approach to food products labeled as organic and suggests that physiological (implicit) responses can provide additional information to further understand consumer preference formation for organic food consumption. Our experimental approach could be used as a starting point to combine explicit and implicit measures to investigate and promote a dietary shift toward healthier, more environmentally sustainable consumer behavior.

CRediT authorship contribution statement

Giulia D'Adamo: Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Giulia Andreani:** Writing – review & editing, Validation, Investigation, Formal analysis, Conceptualization. **Martina Ardizzi:** Writing – review & editing, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Francesca Ferroni:** Writing – review & editing, Validation, Methodology, Data curation, Conceptualization. **Doriana De Marco:** Validation, Methodology, Investigation, Formal analysis, Data curation. **Daniele Asioli:** Writing – review & editing, Validation, Conceptualization. **Giovanni Sogari:** Writing – review & editing, Validation, Methodology, Investigation, Data curation, Conceptualization. **Maria Alessandra Umiltà:** Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization.

Ethical statement

All participants provided written informed consent. Research have been performed in accordance with the Declaration of Helsinki and have been approved by the local University Research Ethics Board (Protocol number: 9294).

The following kinematic variables were analyzed to understand the dynamics of the reaching and grasping movements in the study.

- Maximal Grip Aperture: The maximum distance between the thumb and fingers during the grip phase of a reaching movement, indicative of the planning and control of hand shaping. Measured in millimeters (mm).

- Peak Velocity of Grip Aperture: The highest speed at which the fingers move away from or towards each other during the grip phase, reflecting the dynamics of grip adjustment. Measured in millimeters per second (mm/s).
- Peak Acceleration of Grip Aperture: The highest rate of change in velocity during the opening or closing of the grip, providing insights into the motor control processes involved in rapid adjustments. Measured in millimeters per second squared (mm/s^2).
- Percentage of the Duration of the Grip Aperture: The proportion of the total movement time during which the hand remains in the grip aperture phase, indicating the temporal dynamics of grasp control. Measured as a percentage (%).
- Peak Acceleration: The highest rate of change of velocity of the reaching hand, which is crucial for understanding the initiation and force of the movement. Measured in millimeters per second squared (mm/s^2).
- Peak Velocity: The maximum speed achieved by the hand during the reaching movement, used to assess the efficiency and smoothness of the action. Measured in millimeters per second (mm/s).
- Peak Deceleration: The highest rate of decrease in velocity of the reaching hand, important for understanding how the movement is controlled as it approaches the target. Measured in millimeters per second squared (mm/s^2).
- Maximum Curvature of the Reaching Movement: The greatest deviation of the reaching trajectory from a straight line, indicating the complexity of the movement path and potential corrections made during the reach. Measured in millimeters (mm).

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Declaration of competing interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.appet.2025.107865.

Data availability

Data from this study will be made available on request.

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