ENHANCING HUMAN-PRODUCT INTERACTION PERFORMANCE: A KANSEI ENGINEERING APPROACH TO REDESIGNING THE TRADITIONAL TURKISH COFFEE POT

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ABSTRACT

Traditional craft products possess a strong cultural heritage, yet they often fall short of modern ergonomics and Human-Product Interaction (HPI) standards. This study presents an "Archetypal Optimization" model aimed at eliminating the negative emotional perceptions (Kansei) caused by the physical constraints of the traditional Turkish coffee pot (*cezve*). Within the scope of the research, 80 critical user feedback points focusing on design constraints across e-commerce platforms were analyzed using Thematic Analysis, and form-related complaints were mapped to negative Kansei adjectives (Tiring, Unsafe, Incompetent). To resolve these issues, parametric simulations were performed using Digital Human Modeling (DHM). The traditional 120° handle angle was found to force the wrist into ulnar deviation; by optimizing this axis to 145°, the RULA (Rapid Upper Limb Assessment) score was reduced from 6 to 2 (safe zone). Furthermore, a "U" shaped pouring spout design that resolves hydrodynamic issues was introduced, and haptic integrity was achieved through the material contrast between polished copper and solid wood. This study provides measurable evidence demonstrating how physical performance enhancements translate immediately into positive Kansei perceptions (Professional, Controlled, Safe) within the user's psychology.

Keywords: *Kansei Engineering, Archetypal Optimization, RULA, Human-Product Interaction, Turkish Coffee Pot.*

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1. INTRODUCTION AND PROBLEM DEFINITION

1.1. Traditional Context, Thermodynamics, and Invisible Labor

The traditional *cezve*, at the center of the Turkish coffee ritual inscribed on the UNESCO Representative List of the Intangible Cultural Heritage of Humanity, is a cultural archetype reflecting centuries of craft heritage and thermodynamic necessities with its wide base and narrow neck. Although electric models have automated the brewing process in recent years, the handle ergonomics of the product, the pouring action, and the emotional perception this classical form evokes in the user have been largely ignored. In particular, traditional stovetop use awaits an analytical optimization in terms of modern Human-Product Interaction (HPI) standards. However, in today's design approach, functional performance is not the only expectation from such objects carrying the "invisible labor" of artisans; users now seek haptic satisfaction, physical safety, and cognitive comfort within this experience.

1.2. Physical and Biomechanical Problem Definition

An examination of existing *cezve* typologies reveals that product geometry creates two fundamental engineering and ergonomic problems that directly undermine the user experience:

Spout and Flow Instability: Sharp "V"-shaped pouring spouts, a constraint of traditional manufacturing, disrupt the fluid dynamics during the transfer of coffee into the cup. The liquid sticking to the metal body and trickling down due to surface tension (Coanda effect) and the turbulence created by the narrow cross-section lead to both splashing and the loss of *crema*, the most valuable part of the ritual (Keller, 1957).

Postural Fatigue and Asymmetry: In standard designs, attaching the handle to the body at an angle close to 120°, combined with a shifting center of mass during pouring, forces the user's wrist into severe pronation and ulnar deviation. This postural deviation, corresponding to high risk scores in RULA analyses, causes acute fatigue (McAtamney & Corlett, 1993), while the fact that designs generally only allow right-handed use excludes universal design principles.

1.3. Research Objective and Scope

Physical and biomechanical deficiencies directly damage the emotional bond between the user and the product. Instead of radically altering the traditional *cezve* typology, this study aims to optimize the existing archetype through Kansei Engineering principles. Eliminating negative Kansei perceptions such as "Tiring", "Unsafe", and "Incompetent" distilled from consumer complaints is the primary objective of this research. Accordingly, a novel form synthesis (Nagamachi, 1995) has been developed to evoke feelings of "Safe", "Fluent", and "Professional" in the user by utilizing a wide "U" pouring spout that stabilizes fluid dynamics, a 145° biomechanical handle angle, and a copper-wood material contrast.

2. LITERATURE REVIEW

2.1. Kansei Engineering and Human-Product Interaction (HPI)

Kansei Engineering (KE) is a proactive methodology that transforms a user's abstract psychological responses to a product into concrete design parameters (Nagamachi, 1995). Schütte (2005) defines KE as a bridge linking abstract emotional states like "safe" or "tiring" to mathematical forms, geometric curves, and material decisions. Optimizing grip comfort and reducing the cognitive strain caused by the pouring action in cultural objects directly manipulated by hand, such as the *cezve*, directly enhances the emotional quality of Human-Product Interaction (HPI).

2.2. Modernization of Traditional Craft and Archetypal Optimization

In designs carrying cultural heritage, preserving product DNA (the archetype) is critical for maintaining the user's sense of belonging (Moalosi et al., 2010). With its centuries-old history, the *cezve* is a successful archetype that has already resolved functional dynamics such as heat transfer and foam preservation. Therefore, rather than alienating these deep-rooted forms through radical innovation, it is necessary to improve their ergonomic and sensory weaknesses using the "Archetypal Optimization" approach. When supported by modern hydrodynamic and biomechanical validations, this heritage typology carrying the invisible labor of artisans transforms into a high value-added contemporary design object.

2.3. Biomechanical Performance and Haptic Perception

In manipulative tools, the physical form determines the user's biomechanical health, while material selection dictates the tactile (haptic) experience. Incorrect angles in handled utensils deflect the wrist from its neutral axis (*ulnar/radial deviation*), leading to acute musculoskeletal fatigue (McAtamney & Corlett, 1993). Beyond physical ergonomics, material contrasts also influence Kansei perception. Experiential material combinations, such as smooth-cold metal and textured-warm wood, create feelings of trust, craftsmanship, and quality in the user (Karana et al., 2014). In this context, it is evident that the uniform metal texture and the body-straining handle angle of the traditional *cezve* must undergo a biomechanical and haptic optimization.

3. METHODOLOGY AND DATA ANALYSIS

3.1. Data Universe and Sample Selection

This research aims to map the relationship between the physical form of the traditional *cezve* and the user's sensory perceptions (Kansei). The data universe of the study consists of customer experiences compiled from the three most popular e-commerce platforms in Türkiye. To detect existing design flaws in the market, feedback from the last 24 months was scanned, and 80 critical data points were filtered. Since high-rated reviews in the Kansei Engineering perspective often contain expressions too abstract to be translated into design, only 1-to-3-star feedback focusing on moments of *functional frustration* experienced directly with the product geometry was included in the analysis.

3.2. Thematic Coding and User Voice

The collected qualitative data were coded using the Thematic Analysis method to provide a systematic structure to complex everyday language patterns (Braun & Clarke, 2006). The form architecture of the *cezve* was divided into five main themes: handle, neck, spout, body, and material. Users' daily complaints were directly translated into industrial design and engineering

terminology (*Coanda effect, ulnar deviation, thermal conductivity*). Some critical user experiences isolated from the 80-data pool are as follows:

Handle Ergonomics (Ulnar Deviation): "The handle angle is so steep... I have to bend my wrist excessively just to pour the coffee. It feels both unstable and tires my wrist a lot." (Data #05)

Spout Hydrodynamics (Coanda Effect): "The pouring spout is too narrow... The liquid constantly trickles down the body, and the foam is wasted before reaching the cup." (Data #36)

Body Form (Geometric Constraint): "The base is very wide but the neck is nonsensically narrow. It is impossible to clean the inside with a sponge; coffee grounds always remain in the corners." (Data #22)

Material and Haptic Perception (Kansei): "Its metal is thin as paper and the grip handle is slippery. It gives no sense of security when I hold it; it feels cheap and dangerous." (Data #11)

3.3. Kansei Inference and Semantic Mapping

Following the thematic analysis, the negative emotions evoked in the user's psychology by the identified technical flaws were mapped with reference to the Semantic Differential (SD) scale, which forms the basis of Kansei measurement (Osgood et al., 1957). The negative Kansei adjectives triggered by these technical design errors extracted from user experiences were classified according to their frequencies. This strategic mapping process revealed the foundational design guideline matrix (**Table 1**), which clarifies the positive emotions ("Safe", "Fluent", "Professional") that the newly designed product form should target during the Archetypal Optimization phase.

Table 1. Thematic analysis and Kansei Engineering mapping of traditional *cezve* user complaints (N=80).

Form Component	Frequency	Dominant Technical/Ergonomic Flaws	Evoked Negative Kansei	Optimization Target (Positive Kansei)
Handle	41%	High Thermal Conductivity, Static Instability, Weak Mechanical Connection, Incorrect Axis Angle (Ulnar Deviation)	Anxious, Unsafe, Tiring, Exclusive	Safe, Ergonomic, Balanced, Inclusive
Spout	27%	Surface Tension Flaws (Coanda Effect), Disrupted Laminar Flow, Foam Distribution Flaw	Uncontrolled, Incompetent, Messy	Fluent, Precise, Professional, Clean
Body	14%	Insufficient Base Diameter, Lack of Radius in Internal Geometry (Grounds Accumulation), Mass Distribution Flaw	Bulky, Laborious, Unstable	Practical, Balanced, Fitted, Dynamic

Material	12%	Chemical Leaching (Metallic Taste/Odor), Coating Instability, Low Thermal Shock Resistance	Toxic, Poor Quality, Flimsy	Healthy, Craftsmanship, Premium, Pure
Volume	6%	Capacity Illusion (Misleading Volume), Incorrect Anthropometric Form	Misleading, Dangerous	Transparent, Controlled, Honest

4. PROPOSED DESIGN SYNTHESIS

4.1. Parametric Form Exploration, Biomechanical Optimization, and RULA Analysis

Rather than creating a radical and culturally alien rupture in the traditional *cezve* form, an "Archetypal Optimization" process was conducted based on measurable engineering criteria. In line with Norman's (2004) behavioral design principles, the final geometry of the form was shaped through successive kinematic simulations. Handle Axis Iteration (120° to 145° Transition): To resolve the ulnar deviation problem caused by the steep handle angle of standard *cezves* on the user's wrist, the handle axis was analyzed parametrically. To eliminate human-induced error margins in physical testing, a Digital Human Modeling (DHM) approach was preferred. When the pouring action was simulated with the traditional 120° angle, shoulder flexion (*Upper Arm*) spiked into the 20°–45° range, triggering postural risk, while the wrist bending angle deviated by more than 15° from the neutral axis, causing severe ulnar deviation. When the handle axis reached 145°, shoulder flexion decreased to the 0°–20° range, which is optimal for human anatomy, wrist rotation was zeroed to a neutral position, and the center of mass achieved a perfect balance. The RULA sub-score distributions resulting from these parametric tests, presented in **Figure 1**, clearly demonstrate the direct impact of handle angle modification on body mechanics. By evolving the angle from 120° to 145°, joint loads were reduced to minimum levels, eliminating the feelings of "Tiring" and "Unsafe" to build a "Controlled" and "Professional" Kansei perception.

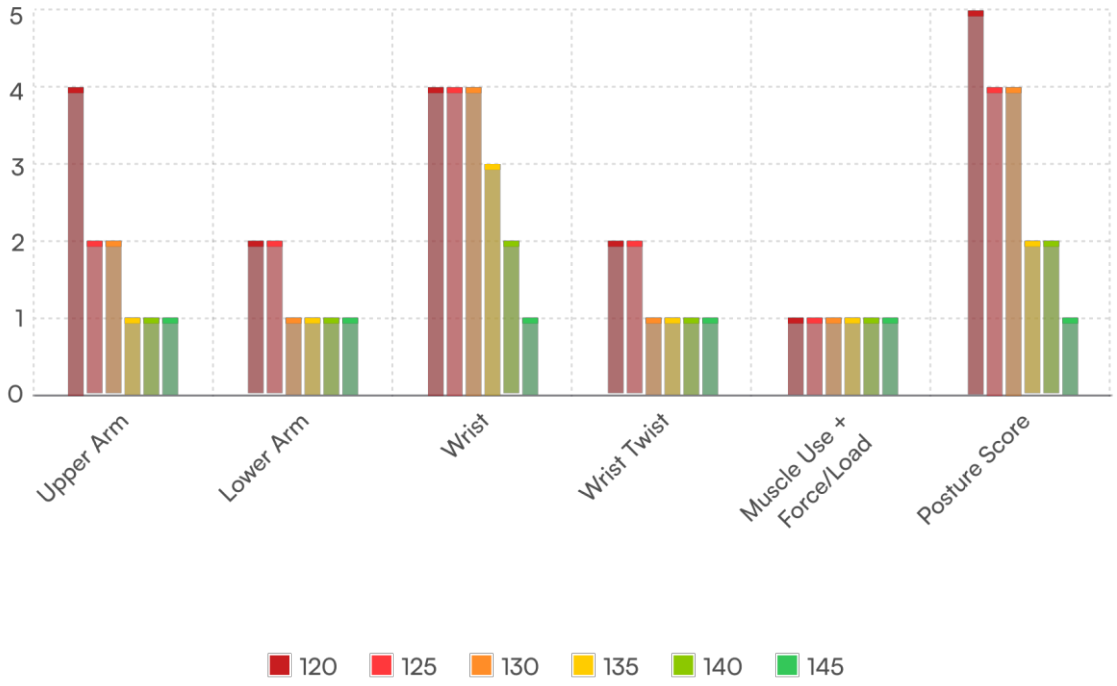

Figure 1. RULA sub-score distributions and postural risk analysis across different *cezve* handle angle iterations.

4.2. Spout Hydrodynamics and Flow Optimization

Transition from Sharp "V" Form to Teardrop "U" Form: The sharp "V"-shaped spout structure, a byproduct of traditional manufacturing methods, creates surface tension during pouring, causing the liquid to adhere to the body (known as the Coanda effect) (Keller, 1957). To solve this hydrodynamic problem, a wide and organic "U" (teardrop) spout geometry was designed to clarify the fluid's break-off point. This wide cross-section allows the coffee to glide into the cup via a laminar flow without entering turbulence, thereby preserving the traditional foam (*crema*) texture. Consequently, the negative Kansei perceptions of "Unsafe" and "Incompetent" triggered by uncontrolled pouring are transformed into the "Fluent" and "Precise" feelings shown in **Figure 4**, thanks to the hydrodynamic stability of the form.



Figure 2. Final design concept and optimized fluid dynamics of the proposed pouring spout.

4.3. Body Geometry

Sharp base-to-neck transitions in traditional *cezves* both disrupt heat circulation and cause coffee grounds to accumulate in the bottom corners, creating a functional barrier to cleaning. In the proposed design, these rigid transitions are resolved with a tectonic and organic curve featuring G2/G3 surface continuity (*curvature continuity*). This holistic flow within the form erases the "Bulky" and "Laborious" perceptions evoked by the traditional typology, giving the product a "Holistic" and "Ergonomic" Kansei value embodied in **Figure 3.**



Figure 3. Surface continuity (G2/G3) and holistic body geometry of the optimized design.

4.4. Material Selection and Haptic Kansei Perception

To preserve the cultural DNA of the product, the traditional copper and wood material palette was maintained, but optimizations were made to improve the tactile (haptic) and thermal user experience (Ashby & Johnson, 2013). Body (Polished Copper): Chosen to reflect cultural DNA, the copper body prevents temperature fluctuations with its high thermal conductivity, supporting the traditional slow brewing ritual. The high-gloss polished surface finish emphasizes the "Pure" character of the material, offering the user a refined craft experience. Handle (Walnut Wood): To counter the high thermal conductivity of copper, a brass ring (*heat break*) and solid walnut have been integrated into the body-handle interface. While the open-pore structure of the wood increases grip security (*affordance*), it generates the "Craftsmanship" and "Premium" Kansei perceptions targeted in **Table 1** through the material contrast showcased in **Figure 2.**



Figure 4. Material execution, haptic contrast, and the brass heat-break interface.

5. DISCUSSION

This study demonstrates that Kansei Engineering is not merely an aesthetic stylization tool; rather, it offers an analytical approach that guides user psychology in solving biomechanical and hydrodynamic problems. While Kansei applications in the literature are generally concentrated in modern sectors such as automotive or electronics (Nagamachi, 1995), this research contributes a unique context to the literature by focusing on the ergonomic modernization of a traditional cultural object (the *cezve*).

The research findings demonstrate the direct impact of physical performance on emotional perception. The perceptions of "Tiring" and "Unsafe" identified in **Table 1** are not related to the product's visual appearance alone; they are directly linked to the ulnar deviation caused by the traditional 120° handle. The radical drop in RULA scores achieved through the 145° axis optimization (**Figure 1**) validates how removing physical constraints immediately triggers the

feelings of trust and control that Norman (2004) conceptualizes at the *behavioral level*. At the exact point where physical fatigue is reduced, a "Professional" and "Controlled" Kansei perception begins.

Furthermore, arguments asserting that cultural DNA must be preserved (Moalosi et al., 2010) are put into practice through the "Archetypal Optimization" applied in this study. Instead of forcing the product into an alien or overly futuristic form, the familiar archetype was maintained using seamless G2/G3 surface continuity and a "U"-shaped pouring spout. Material perception, as emphasized by Ashby and Johnson (2013), was constructed through the haptic contrast between the thermal quality of polished copper and the open-pore texture of solid wood. This synthesis combines the user's expectation for a "Craftsmanship" and "Premium" product with the flow stability brought by modern engineering.

5.1. Limitations of the Study and Future Research Directions

The primary limitation of this study is that ulnar deviation and biomechanical tests were conducted using Digital Human Modeling (DHM) simulations rather than physical prototypes. Although simulations provide highly reliable anthropometric data, physical interaction is essential to measure actual thermal perception and haptic feedback during use. In future studies, it is planned to produce functional prototypes of the proposed design to conduct muscle activation tests on users via Electromyography (EMG) and to validate Kansei outcomes in a laboratory environment through Semantic Differential questionnaires.

6. CONCLUSION

This research has mapped the negative Kansei reflections in user psychology caused by structural and hydrodynamic constraints in the morphology of the traditional Turkish coffee *cezve*, and has optimized these limitations through measurable design parameters. In a process that began with the thematic analysis of 80 users, the postural risk score (RULA) was reduced from 6 to 2 by evolving the traditional 120° handle angle to 145°. Pouring control was enhanced through a laminar-flow-oriented "U" (teardrop) form replacing the sharp "V" spout structure, while the targeted perceptions of "Craftsmanship" and "Premium" were materialized through seamless surface continuity in the body and haptic contrast in the material palette.

Consequently, this study offers a methodological model demonstrating how archetypal objects identified with cultural heritage can be transformed using modern biomechanical and sensory design (Kansei) principles without losing their authentic identity. The developed "Archetypal Optimization" approach is envisioned to guide the modernization processes of other traditional objects that establish physical contact with humans in the future.

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