

Kansei for the Digital Era

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Abstract: For over 40 years, Kansei-based research and development have been conducted in Japan and other East Asian countries and these decades of research have influenced Kansei interpretation. New methods and applications, including virtual reality and artificial intelligence, have emerged since the millennium, as the Kansei concept has spread throughout Europe and the rest of the world. This paper reviews past literature and industrial experience, offering a comprehensive understanding of Kansei, the underlying philosophy, and the methodology of Kansei Engineering from the approach of psychology and physiology, both qualitatively and quantitatively. The breadth of Kansei is described by examples, emerging from both industry and academia. Additionally, thematic mapping of the state-of-the-art as well as an outlook are derived from feedback obtained from structured interview of thirty-five of the most distinguished researchers in Kansei. The mapping provides insights into current trends and future directions. Kansei is unique because it includes the consideration of emotion in the design of products and services. The paper aims at becoming a reference for researchers, practitioners, and stakeholders across borders and cultures, looking for holistic perspectives on Kansei, Kansei Engineering, and implementation methods. The novelty of the paper resides in the unification of authors amongst pioneers from different parts of the world, spanning across diversified academic backgrounds, knowledge areas and industries.

Keywords: *Affective Design, Artificial Intelligence, Data Analytics, Product Innovation*

1. INTRODUCTION

Kansei is historically based but is becoming increasingly relevant in our digital society, in which user-customized services and products are growing in relevance.

The purpose of this paper is to define the current, wide research field of Kansei, map the most common research-schools, areas and applications as well as providing an outlook of research for the decade ahead. The co-authors have aimed to give a wide and balanced view on Kansei, and have interviewed 35 of the most distinguished researchers in the area in order to map their point of view on both the state of the art and opportunities for future work. The paper therefore presents input from many of the leading researchers in Kansei from all parts of the world to give an overview of the area as it stands today, also giving an outlook into the coming years with challenges in AI, digitalization and societal and environmental changes. Obviously, understanding the challenge to cover every aspect and influx in detail, the authors encourage readers to refer to additional material presented beyond this text.

The paper starts with a definition of the term Kansei and

the research area, describing the state-of-the-art as well as presenting practical means for measuring feeling (the Kansei) and reviewing the most common application areas. The paper commends the uniqueness of the Kansei approach and predicts development trends for the years to come based on existing literature and the authors' expertise.

1.1 Historical Background

For more than 40 years the research area of Kansei has been a means of product development, foremost in Japan, China and Korea. Since the turn of the Millennium the idea of Kansei in product development has been spreading to other geographical areas in Europe and the rest of the world. Several groups have been founded promoting the idea of Kansei including regional organizations such as the Japanese Society of Kansei Engineering; JSKE (2007), European Kansei Group; EKG (2014), Taiwan Institute of Kansei; TIK (2007) and Malaysia Association of Kansei Engineering; MAKE (2017). The bi-annual Kansei Engineering and Emotional Research (KEER) conference has evolved from just being a meeting to being an umbrella organization for research on the topic. The diversity of interdisciplinary, technical and cultural perspectives has fostered wider interpretations of Kansei

and inspired the creation of diverse methods and applications. The community embraces the influx of these different approaches and offers them a home for exchange of ideas and further development.

As seen later in the paper the term “Kansei” is a Japanese word meaning affect, emotion or feeling. The first methods originated in Japan and the term is now an established way to describe the whole area of research. During the last 40 years of its existence, Kansei has developed from a psychological method connecting rudimentary emotional expressions with product features, into a complex collection of affective product development methods with a wide variety of approaches, tools and applications.

1.2. The Mystique of Kansei

The term “Kansei” is Japanese in origin. Translated into English it means roughly “feel, emotion or affect”, but as with many terms in Japanese, its real meaning only becomes apparent in conjunction with a corresponding term. In a contemporary dictionary, the term Kansei is usually listed in conjunction with secondary, explanatory expressions - such as Kansei *Engineering* or Kansei *Technology* but also Kansei *Poetry* or Kansei *food*. Here also the imperative of “brush up your Kansei” meaning to sharpen up and improve attitude can be found. It seems as if the term Kansei in many contexts adds an emotional-affective dimension to the corresponding word.

Obviously, the term Kansei is hard to define; it stems from a long Japanese tradition and hence seems closely connected to Japanese culture and philosophy. To the foreign observer’s eye this transient meaning imparts a certain mystique to the term Kansei. It is also this ambivalence, which makes the term Kansei desirable for a novel dimension of research. In contrast to other terms in the research field (affective, emotional, etc.) it still holds a degree of purity and novelty which allows researchers to newly define research related to affect, emotion, and personal preferences.

As an example: In the context of product development, the expression of Kansei describes an affective approach by product developers. Typically, product development methods use fact-based input to achieve customer satisfaction. These needs are mostly functional. Kansei adds an emotional facet to product development and enables traditional product developers to cope with mostly qualitative, affective input data to reach emotionally pleasing products.

This, however, does not necessarily mean that it is used in the same manner by each practitioner. Due to its

ambiguity, many researchers and practitioners have found and published their own definitions to promote their personal take on the field. What a first glance can seem like a chaos of definitions is a rich source of novel ideas and approaches and is widely seen as an advantage.

2. DEFINING KANSEI

Kansei is a linguistic concept, which can be traced back to XVII century Japanese literature [1]. It has been roughly translated to want, need, affect, emotion, sense, sensitivity, sensibility, feeling, customer’s feeling and need relating to a product [2]. A more literal translation is “the faculty of feeling” [1] as in a person’s ability to feel and to be aware of such feelings. Nagamachi has defined Kansei as the “individual’s subjective impression from a certain artefact, environment, or situation using all the senses of sight, hearing, feeling, smell, taste as well as recognition” [3]. There is an analogy to *Gestalt* psychology: Kansei is the affection arisen from becoming aware of the *gestalt* in an experience. However, Kansei itself cannot be observed, only its causes and the consequences of the experience [3]. Kansei can only be indirectly and partially assessed through measuring how our senses react (psycho-physiological responses) and what meaning (behavioural responses) are given to it [3].

Kansei Engineering (KE) sees the Kansei concept applied to product design. Consumer’s feelings and overall impressions are regarded as perceptual design elements and, along with the product or service physical attributes, through a reductionist approach, are broken down and prioritized. From its essential parts, a model of Kansei is constructed based on the most important and determinant factors of the product [4]. KE has been also denominated as “sensory engineering”, “emotional usability” [5], “emotional engineering”, “affective engineering” and others alike [4].

There is a lively discussion about the definition of the area of Kansei. There are different opinions, all valid but not all compatible with each other. Amongst these competing views, the authors choose to focus on one particular angle for the sake of proceeding with a review of the concept of Kansei. The viewpoint we have chosen, therefore, follows Professor Nagamachi’s original idea of capturing the Kansei and modifying a product or service accordingly.

3. MEASURING KANSEI

3.1. General Principles When Measuring the Kansei

Measuring emotions is key to understanding our relationship with products and services. In this section we describe measurement techniques, also considering that technology is enabling ever more subtle and powerful ways to measure emotions.

Kansei measurement, in common with all kind of measurements, has to be valid and reliable [6]. Validity is related to really measuring what we want to measure, representing the ground truth of people's emotions; reliability refers to the consistency of a measurement. The problem of validity and reliability is particularly difficult in Kansei because of the ephemeral, intangible nature of emotion and it is important that researchers give thoughtful consideration to these aspects. Kansei measurement also needs to take into account shifts in emotional response over time.

In the data-driven approach to understanding emotion, human Kansei is commonly collected using psychological or physiological responses or combining both sources. Many methods for quantifying experience towards understanding Kansei are available to researchers, with a high-level overview and summary of such tools available represented in **Figure 1**. As Kansei measurement implies working with data, statistics has an important role to play – particularly, the use of design of experiments, regression, modelling and multivariate analysis, among others [7]. Increasingly machine learning data analytic techniques are being applied to the data [8]. Data science linking IT, statistics and domain knowledge has a lot to offer in the current era of industry 4.0 in which sensors and machines communicate and even learn with each other, providing feedback towards continuous improvement [9].

As always when capturing data coming from individuals, there are ethical questions that need to be addressed. This is particularly relevant in the context of Kansei measurement, where we are trying to capture information that might be unknown even to the study participant

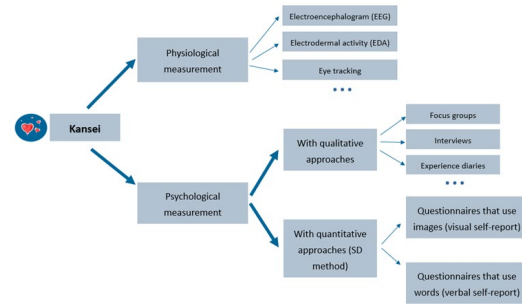


Figure 1: Methods used to measure the Kansei.

3.2. Psychological Measurement

One of the forerunners of Kansei in product development was Mitsuo Nagamachi in the 1970s (as in Nagamachi, 2017). His background was product psychology, so many methods used in the beginning derived from psychological science. Psychological responses require self-reporting, either using images or words. Using words is the most common option. When giving ratings to prototypes, semantic differential (SD) method is the most common approach [11]. For example, Van Lottum et al. [12] ask respondents to score men's everyday shoes from 1 to 5 on semantic differential scales such as fashionable - unfashionable, casual - formal, etc.

Charles E. Osgood developed semantic differential theory in the mid-1950s. The semantic differential analyses connote meaning by plentiful evaluation words. An adjective is paired with its antonym, like “realistic - idealistic.” Between this pair of words, a Likert scale is placed, commonly having 5-grades or 7-grades between the words. Osgood used 50 to 80-word pairs in his evaluation [13].

Different evaluation word pairs may reflect similar underlying factors and they may give rise to correlated responses. Often a principal component analysis is used to extract these general factors, defining the semantic space.

Osgood used polarized antonyms like “beautiful - ugly” (**Figure 2**). In Kansei engineering, the common recommendation is to use the denial word (beautiful - not beautiful) instead. According to Schütte et al., 2004 two main reasons can be found in literature for this recommendation:

When using antonyms such as “beautiful - ugly”, the statistical frequency distribution tends to be distorted towards positive, in this example the “good” side. Skewed distributed data cannot be used in later named statistical analysis tools [15]. Many semantic meanings do not have an antonym. For example, what is the antonym of “fashionable”? Using “fashionable - not fashionable”

avoids such a semantic problem.

Osgood’s original semantic differential scale:

Ugly Beautiful

Adaptation of Osgood’s semantic differential scale used in Kansei Engineering

Not beautiful Beautiful

Visual-analogue scale used in Kansei Engineering

Not at all Beautiful Very much

Figure 2: Modified Semantic Differential scales used for Kansei engineering [4]

Ordinal scales with 7 points are commonly placed between the two extremes. Commonly, even 5 and 9 point scales can be adopted, in accordance to Miller’s research (1956). From a statistical point of view, considerations regarding the use of discrete or continuous sets of data should be taken on the selection and limitations of analysis tools to be used (Norman, G., 2010).

Hence a continuous scale can be advantageous as it often can be found in European case studies. In these so called Visual-Analogue Scales (VAS) the respondents mark their opinion on a position along a continuous line between two end-points as shown in **Figure 2**. This mark is later converted into a number (usually from 0 to 100). It can also be observed that VAS scales are perceived more intuitive by the respondents than ordinal scales since they allow a higher degree of freedom in their decisions. Also, studies using VAS imply that this type of rating is faster.

The words used on those scales are in literature commonly referred to as “Kansei words”. Typically, they are adjectives since they easier can convey a feeling. However, in exceptional cases where no suitable adjective does suffice, nouns can also be used.

3.3. Physiological Measurement

EEG (electroencephalogram) measurement and analysis techniques were pioneered by the late Professor Tomoyuki Yoshida. Yoshida measured the frequency and number of fluctuations (Yuragi in Japanese) of the alpha wave (8 to 13 Hz) from the frontal lobe (Fp1, Fp2). He unveiled relations between active tasks and resting or more tranquil comfort periods, labelled by the authors as relaxed feeling.

Graphical representation of alpha wave elements was extracted by digital frequency filtering. Frequencies of the samples in a period shape a statistical distribution are shown in **Figure 3**.

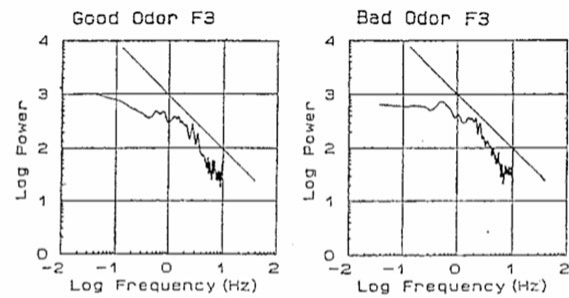


Figure 3: Fluctuation distribution of alpha wave on smell experiment [16].

The gradient of the plot on the lower frequency domain has a strong association with comfort and relaxed feeling. A steeper gradient approaching the straight line with a higher frequency domain is strongly associated with subjective comfort feeling; while less comfort is associated with a flat plot. From his many research results, Yoshida made a basic emotion model composed of two axes, arousal feeling (excitement/calm) and comfort / uncomforted [17]. Mathematical brain theory is expected to push forward Kansei brain science methodology, offering many research opportunities to further explore such physiological measurement capabilities. Other less common sources of physiological data input are electrodermal activity (EDA), electromyography (EMG). Depending on the case-study, bodily movements can be monitored with the adoption of novel technologies for visual tracking. Examples can be found, including outside Kansei research, from the automotive, consumer electronics (e.g. computer peripherals) and sports science offer examples of eye tracking, posture tracking, arm, hand and finger tracking. The main problem with data from these sources seems to be their unspecific nature and therefore hybrid studies with psychological measurements often provide better accuracy.

3.4. Mathematical Principles and Laws of Kansei

Studies on mathematical principles of perception [18] and emotion [19,20,21] have been developing recently. These principles will provide a fundamental framework for modelling Kansei.

Yanagisawa et al. [18] formulated human perception bias by prior expectation based on two neural coding principles: efficient coding and Bayesian decoding, as represented in **Figure 4**. Expectations affect perceptions of

subsequent experiences. This perceptual phenomenon is known as expectation effect [22,23]. Yanagisawa [24] elucidated the mechanism of expectation effect using the perception model. Figure 5 shows the schematic of the Bayesian estimation (or perception model). The peak of posterior belief represents the estimate (i.e., the percept). The posterior is proportional to a product of prior belief (or expectation) and likelihood function (or sensation). The gap between posterior and likelihood is the expectation effect.

Yanagisawa's functional model of expectation effect [24] predicts how expectation biases affect perception in general. The model has been applied to hypothesize multimodal perceptions of product design [25] and to model feelings of safety of autonomous vehicle behaviour [26].

The Bayesian model of perception is applied to formalize dominant emotion dimensions such as arousal (i.e., intensity) and valence (i.e., positivity and negativity). Yanagisawa et al. elucidated that information gain formulated as Kullback-Leibler divergence between Bayesian posterior and prior represents emotional arousal induced by novel stimuli, i.e. an opportunity to experience Kansei, and the emotional valence, the value or meaning given to Kansei. This divergence forms the inverse-U shape function of the information gain, so called Wundt curve [27]. The arousal model is generalized using free-energy, a measure of cognitive availability, representing potential information contents to be processed in the brain [28]. Free-energy has been recently recognized as a quantity to unify brain theories of perception and action [29]. Emotions are aroused by perception and motivate action. Therefore, free energy is expected to be an essential quantity for modelling emotions in a general manner.

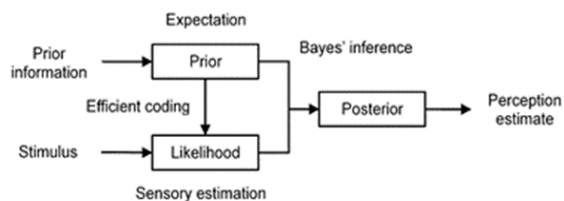


Figure 4: Perception model diagram principles[24].

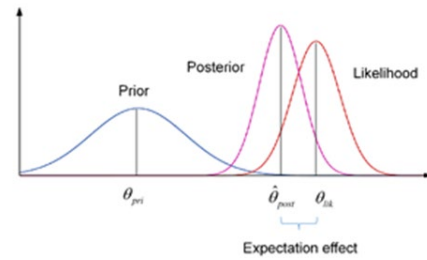


Figure 5: Bayesian perception effect [24]

The prediction model is expected to be a general law of sensory perception affected by prior experience. The model aims at combining, in the present, the cognitive availability to experience Kansei and its immediate response but also the meaning given to such experience, presently but also formed by prior experience, while shaping future expectations.

4. KANSEI ENGINEERING

Kansei Engineering (KE) is a methodology that unites Kansei into engineering fields in order to realize products and services that match consumers' implicit needs and desires [30]. It provides a means to translate implicit requirements for the affective quality of human interaction into the explicit and aesthetic properties that can be designed into products [31]. This is achieved by identifying how the affective experience (such as pleasure, trust, and engagement) of a product or service influences consumers' responses; and manipulating the specific properties or features of the product or service that determine the response.

The basic KE methodology for Kansei evaluation and analysis was established in the middle of the 1980s [32][33]. In the early stages, Nagamachi used the terms "emotion" or "image technology" to represent Kansei in his methodology. The term 'Kansei Engineering' was first used in 1986, after establishing the basic methodology [34]. During 1980s, foremost Japanese industry; namely automotive industry (Mazda, Nissan), and electric home appliances (Sharp, Panasonic) have incorporated Kansei engineering as their important development process.

The first KE paper in English was published in 1988, and focused on home interior and garment expert systems [32][33]. It comprehensively explains KE measurement, multivariate analysis, and expert system building. Then, the International Journal of Industrial Ergonomics had the first special edition of KE in 1995. Ishihara et al. (1995) presents ART1.5-SSS self-organizing neural network-based clustering, learning result extraction, and

automatic expert system building. Jindo et al. (1995) explain the product improvement process with KE in detail, and then show 3-D graphics prototyping.

In 2004, Schütte, Eklund, Axelsson and Nagamachi proposed a general model on Kansei Engineering procedure. It includes a list of methods and tools that can be used in industry's existing product development processes. The model is a summary of all current Kansei Engineering types. It is presented in Figure 6.

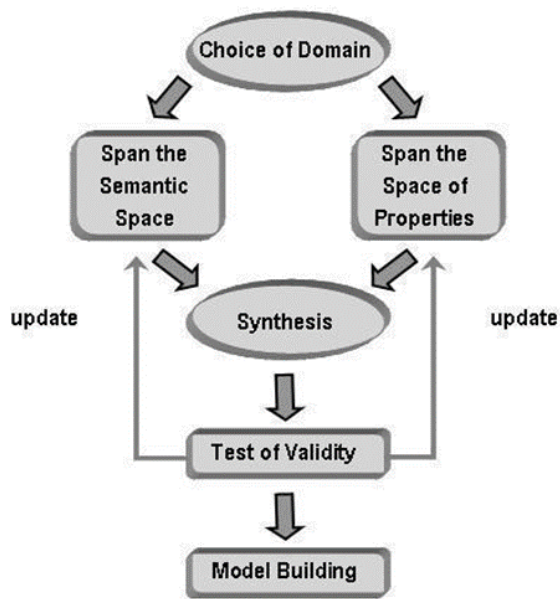


Figure 6: Kansei Engineering model proposed by Schütte, Eklund, Axelsson, & Nagamachi [14].

Based on that model the idea behind the product can be defined from two different viewpoints. The Semantic Space collects consumers' affective needs of the new product. The description of product properties in turn includes the physical properties of the product which can be manipulated by the product designer. The synthesis phase is unique to the Kansei Engineering method. The semantic and physical properties are linked to each other using mathematical statistical tools [4,41]. This makes it possible to determine which of the product properties evokes which affective impact. Product designers can then determine which product features to include and in what way to accomplish the intended affective impression. After these steps have been carried out, it is possible to conduct a validity test, including several types of post-hoc analyses. A prototype is tested against a group of customers. As a result of this step, the Semantic and physical Properties Spaces may be updated, and the synthesis step may be rerun. This process is continued until the methods yield satisfying results. In the final step, a mathematical model is built describing the link between

the Semantic Space and the Space of Properties. This model is then used for the development of a product specification list which in turn is fed back to the specific product development process in the company [41]. This method has been successfully applied in different industrial branches for very different products and demonstrates its versatility. Methods in detail were explained by Lokman [30] and Nagamachi & Lokman [33]

KE encompasses the use of all methods that enable products or services to be designed to better satisfy affective needs.

Researchers now use physiological measurements such as electroencephalography [17] and eye tracking [37], paired with self-report questionnaires using item response theory [38], and making use advanced modelling techniques such as neural network analysis and sparse Bayesian learning [39]. Qualitative research techniques such as empathy mapping and phenomenology can be used [14]. These enable designers to understand how different design solutions influence the affective responses of users.

The diversity of these techniques reflects the diversity of the backgrounds of the researchers, and Kansei in the West has therefore become richly interdisciplinary, overlapping with and complementing design, engineering, psychology, affective computing, human-computer interaction, user-centred design, cultural computing, marketing and business, service design, and neuroscience. This is reflected in the research community by the use of terms such as Kansei Design and Kansei Science. Beyond the Kansei community, others pursue what we would characterize as a Kansei-like approach, even if they do not necessarily recognize the term, such as industry-based consumer researchers [40]

Engineers are often interested in people's affective responses to products and seek to create models relating perceptions to the physical properties of stimuli. Engineers are essential for understanding the physical properties of stimuli and the mechanics of human interactions with them (including the tribology of touch). However, some engineers seek linear relationships between perception and the stimuli's properties where linear relationships are unlikely to exist. One of the significant aspects of KE methodologies is analyzing the non-linear nature of Kansei and measurable physical properties such as colour, shape and surface finish.

The understanding and application of KE is not limited to hardware engineering and even physical products. KE

methods can be applied to digital products, e.g. software or websites, services, and even interactions between user and product that can elicit Kansei. Several case studies are provided in the following sections. The understanding is that Engineering can make use of any of its fields of knowledge applicable to the case-study at hand.

The potential for applying KE methods, well beyond the scope of research performed so far and, undoubtedly, beyond more traditional product design methods, remains vast, somewhat unexplored and should be taken advantage of in future research. It is the authors' expectation that this paper, including case studies referenced herein, highlights the diversity of fields to which KE can be applied to, while teasing researchers for exploring future and novel applications.

5. STATE OF THE ART

A qualitative study was conducted by the authors to give a wider and balanced view of Kansei adoption. Thirty-five of the most active researchers in the area were interviewed about how they felt regarding the state of the art and opportunities for future work in Kansei Engineering (KE) research and implementation. Purposive sampling was done to select the participants from among the active Kansei community in the East and the West. The participants were invited to respond to an email interview which allows them to answer questions at their own pace within a given period of time. Open-ended survey questions were provided via email to obtain rich qualitative data from the participants. The gathered datasets were analysed qualitatively via a thematic clustering process on a digital whiteboard platform. The thematic analysis has resulted in a classification map, presented in Figure 7.

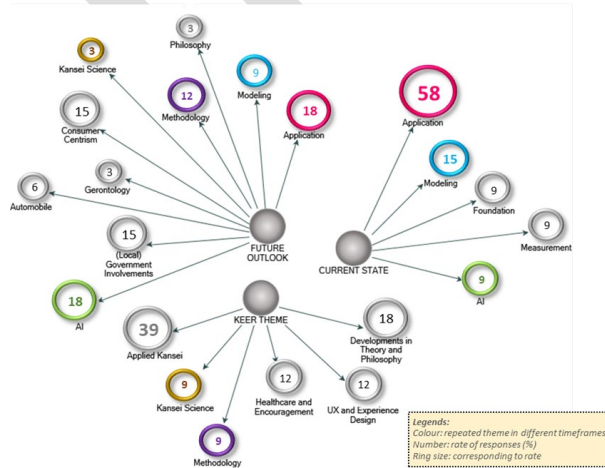


Figure 7: Classification map for the field of Kansei.

We can observe from the Classification map that KE attracts research primarily on the application of KE in diverse domains. Among the domains are hospitality, virtual reality (VR), and consumer products. KE modelling follows, showing the attention on mathematical modelling, geometrical modelling, and computational modelling, among others. The rest of the current research focuses on the foundation of KE, KE measurement, and artificial intelligence (AI). There are many examples of the successful application of Kansei in large corporations and small businesses. In Japan, Kansei Engineering is used by Asahi Breweries and Shiseido personal care products [33]. In Europe, Kansei Engineering has been used to improve the sensory quality of car interiors for the Toyota C-HR (pan-European) [42]; the usability of warehouse trucks for Toyota Material Handling (Global) (Schütte & Eklund, 2001); addressing the unmet requirement for attractive orthopaedic shoes for County Orthopaedic Footwear (UK); and enhancing the development process for charcuterie products for España (Spain); and balancing the delight against the guilt of the consumption of chocolates and fizzy drinks for Cloetta and WellNox respectively (Sweden) [43]. Kansei Engineering methodologies are also being used by Nestlé (Switzerland) [33] and Cartier (France) [44].

Evidently from these observations, the pool of research implementing KE and Kansei-based approaches has grown rapidly throughout the world. This shows that the concept of Kansei is well accepted and gaining scientific attention beyond culture and beliefs for its contribution to the advancement of knowledge in theory and in practice involving people's emotions.

5.1. KEER Theme

KEER, which refers to Kansei Engineering and Emotional Research, is a conference series which gathers scholars and experts from around the world. Created in 2007, KEER hosts an interdisciplinary international conference focusing on the topics of Kansei and emotion (<https://keer.org/keer/>). Figure 8 shows the history of KEER from 2007 until 2022, in which it has been hosted alternately in Asian and European countries every two years. Interesting themes have emerged over time from the introductory 'East and West, Kansei and Emotion' to the latest 'Harmonious Value Creation in Inclusive Society'. The thematic areas in each conference have also evolved from the focus topics on Kansei and Emotion, to multidisciplinary topics, and the most recent, emerging topics. As a way forward, our survey has included the scholars' projection on future topics.

Thematic analysis has provided insights to the anticipated thematic areas for the future KEER conference (in the next 10 years). The scholars in the field expect to have Applied Kansei, Kansei Science, Healthcare and Encouragement, user experience (UX) and Experience Design, and Development in Theory and Philosophy. Automobile industries, consumer electronics, future network technologies, entertainment industries, and a variety of other topics are likely to be covered in Applied Kansei. Development in theory/philosophy is expected to cover topics on UN sustainable development goals (SDGs), human values, culture, Kansei and beyond, and governance. For UX, expected topics include sentiment/mood analysis, deep learning, and internet-based applications. The advent of topics on cyber-human, hospitality, and healthcare product designs are examples of topics in the healthcare area. Other expected themes are Kansei Science, methodology.

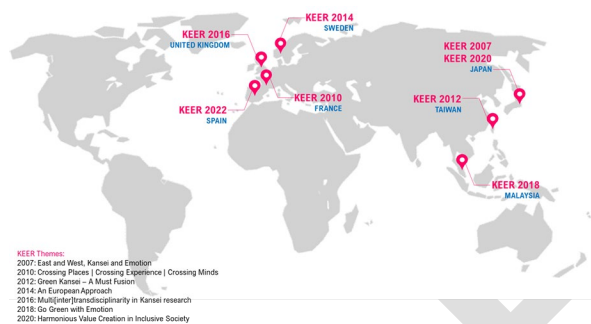


Figure 8: The history of KEER.

This evidence on the evolutions and future insights induces motivation and encouragement on the extending interest by scholars and producers, and thus provide sound support to the sentient and growth of Kansei and Emotion in the future research roadmap.

6. APPLICATIONS

The many diverse applications of Kansei are one of its most appealing features. KE practitioners typically enjoy the interdisciplinary work that is one of KE's key intrinsic, unique aspects. Extracting insight from measuring emotional response to an experience like visiting a beach, or from driving a car is like creating order from chaos. From the many reported case studies, the following sections give a flavor of the rich possibilities of KE research and application extending from physical design issues to the more experiential:

6.1. Automotive manufacturing design

One of the first major applications of Kansei Engineering (KE) in industry was by the Mazda Motor corporation. The Mazda Miata (MX5) car was developed entirely with KE procedures in mind. The car was launched in 1989 and is today the most sold sports roader in the world. Other manufacturers followed suit, and today most major car manufactures use some form of affective design for product innovation. Many studies have been conducted using car or car parts as objects for improvement.

Matsubara et al. [45] studied Kansei on leather grain patterns on car instrument panels with the aim of designing in user appeal. The user is required to compare different panels. However, it is very time-consuming and costly to design and make an actual panel. Instead, the researchers developed a representation of the surface using a laser 3D scanner to precisely measure the surface pattern, and a real-time 3D computer graphics (CG) system. The main advantage of 3D CG is that it is possible to adjust the depth of carving and gloss of the surface by parameters. They found that the representation of surface processing by 3D CG has sufficient quality for Kansei evaluation and that virtual prototyping is promising. The depth of the engraving resulted in different sensory evaluations than expected.

In another example within the industry, Valverde [46] used a statistically designed experiment that generated mechanical push-button multimedia controllers with perceivably distinguishable feedbacks. The prototypes' kinaesthetic and acoustic feedback was measured, and its experimental data post-processed towards an extensive characterization in both haptics [47] and psychoacoustic [48] metrics. This set of experimental data constitutes both the tactile and audible feedback cues afforded to users from such devices and can be related to their design factors providing an array of engineering parameters that explain device behaviour. From the affective response perspective, prototypes were evaluated with sensorial analysis methods by two distinct panels: an original equipment manufacturer (OEM)'s specialist team and a supplier's expert team. From both panels, the prototypes were rated in terms of the sensorial cues that form a holistic perception of quality. Beyond KE quantification tools and statistical analysis methods, experimental data and subjective evaluation data were further integrated using data analytic methods such as Partial Least Squares and Structural Equation Modelling [49]. Quantified relationships were found and established between the metrics and ratings for sensorial cues, and the

unmeasurable construct of perceived quality – the brand sense.

6.2. Packaging

Although the main purpose of packaging is functional – protecting products for distribution and sale – it is obvious that packaging can have an enormous emotional impact, affecting the purchase decision and the user expectations of the product. For this reason, packaging design is a discipline that can benefit a lot from Kansei Engineering.

The literature includes methodological papers that explain how KE can be used for packaging (see, for example, [50]). It is worth noting that the vast majority of case studies refer to food packaging, with a few others relating to cosmetics. Food and cosmetics are products where packaging is especially important in conveying the correct perceptions. When referring to food, the majority of documented case studies are on sweets and candies [51,52,53] and beverages [54,55]. Sometimes, the concern in these studies is not only giving a good impression of the food product, but communicating a coherent idea of the content, so that user expectations are not disappointed. Cosmetics studies refer not only to the visual design of packaging [56], but also to other senses, such as the tactile effect when touching glass in perfume bottles [57,58].

6.3. Consumer Electronics

Consumer electronics are a massive growth area in the digital age with Internet of Things and Industry 4.0 as driving forces. One example of a research case within the industry [46] used a statistically designed experiment that generated mechanical push-button multimedia controllers with perceptibly distinguishable feedbacks. The prototypes' kinaesthetic and acoustic feedback was measured, and its experimental data post-processed towards an extensive characterization and extraction of both haptic metrics [47] and psychoacoustic metrics [48]. This set of experimental data constitutes both the tactile and audible feedback cues afforded to users from such devices, and can be related to their design factors providing an array of engineering parameters that explain device behaviour. From the affective response perspective, prototypes were evaluated with sensorial analysis methods by two distinct panels: an original equipment manufacturer (OEM)'s specialist team and a supplier's expert team. From both panels, the prototypes were rated in terms of the sensorial cues that form a holistic perception of quality. Beyond KE quantification tools and statistical analysis methods, experimental data and

subjective evaluation data were further integrated using methods such as Partial Least Squares – Structural Equation Modelling [59]. Quantified relationships were found and established between the metrics and ratings for sensorial cues, and the unmeasurable construct of perceived quality – the brand sense.

Similar KE methods have been used to explore computer peripherals. The overall “click” feedback when using a computer keyboard is a complex perceptual summation of both tactile and acoustic cues. From the user perspective, integrating these multi-modality cues results in a confirmatory mental process, a sense of achievement for the desired interaction. Embedded in the feedback, there are recognizable emotional qualities emerging from the experience. This elicits a subjective perception of the quality of the interaction and, at a higher level, a contribution to the holistic perception of product quality and promotion of brand sense.

Within these studies, and by exposing users to prototypes affording distinctive feedback, e.g. linear to tactile haptics and quiet to discernibly audible clicks, KE methods can also aim at quantifying suitability and desirability for specific interactions. These vary according to context, such as working from an office and, more recently, the mass-usage of working from home. KE methods have allowed us to explore, discover and unveil new market trends and specific user needs.

6.4. Shoe design in the manufacturing sector

A European Commission funded project to investigate the application of KE in Europe focused on the emotional response to shoes and addressed case studies in men's everyday shoes, orthopaedic shoes and designer costume wear [60]. Using physical examples of different designs and also images of different products, KE was shown to be effective in identifying many subtle impacts of design factors on emotional response. For example, the everyday shoe manufacturer found that coloured shoes rather than black or brown appealed more to men in Spain than in the UK; the desire for style was clearly evident in wearers of orthopaedic shoes; and bespoke fantasy shoes elicited different emotions in the actors depending on the shoe design. The analysis was based on extensive multivariate modelling of questionnaire data including factor analysis and logistic regression. Bespoke statistical software is useful for KE analysis, see for example KeSo, but also much use can be made of standard statistical analysis packages and freely available software such as R and Python.

6.5. Healthcare

Matsubara et al. [45] show that human beings have very high sensitivity for detailed design which is particularly important in orthotics. Morinaga et al. [61] applied recent 3D CG advancements to confirm this finding in research into children's lower leg orthotics. In this example, physically based rendering was applied to represent leather colour, pattern, bump, and glossiness. Twenty-two virtual prototype orthotics with leather pattern variations were made and used for Kansei evaluation. From principal component analysis results, leather surface details were found to be decisive in Kansei evaluation. In particular, it was found that nubuck leathers (buffed surface to raise protein fiber) correspond to juvenile, comfort, lively and lovable. Feminine, soft, natural and tender were consistent with grey nubuck leather. Leather with a large pattern and glossy surface corresponded to cool, western, and chill whereas a dark brown leather with a slightly glossy smaller pattern corresponded to hard, massive, and masculine. Refined, attractive, good sense, and beautiful corresponded to leather with small bump dots in a wavy alignment. These findings can be used to help guide the choice of surface finish and help the patient to accept the orthotic and enhance their well-being.

6.6. Gerontology and gerontechnology

The risk factors of pressure ulcers are body pressure, friction between the body and mattress surface, pressure-induced blood flow inhibition, moisture caused by urination, and poor nutrition. The main contributing factor is gangrenous skin as a result of blood flow inhibition.

Ergonomics and Kansei Engineering were applied to the development of a new mattress that can prevent pressure ulcers, with the newly developed material "breathair" from Toyobo Co. Ltd. The "breathair" has the structure of the 3-dimensional sparsely interwoven polyester fiber; as a result, it is excellent in dispersing load, resilience, and breathability.

Nagamachi et al., (2013) conducted various measurements to find the best mattress to maintain blood flow based on the principles of Ergonomics and Kansei Engineering.

The first evaluation used 63 materials of different breathair and existing mattresses. Then in the second evaluation experiment, Kansei evaluations and pressure distributions were measured with 12 breathair candidates and participants of different weights, from 40 to 108 kg. A variant of breathair has the second-best body weight dispersion and has the best Kansei evaluation. On the

other hand, an air mattress showed the best dispersion, but Kansei evaluation was much poorer because of its instability. Blood flow was also measured.

Finally, five national hospitals participated in the evaluation, and they reported having no more pressure ulcer patients following the introduction of the new mattress. Then, the mattress was commercialized by Panasonic as "Luckmat air."

Nagamachi et al. [63] also applied these type of evaluation techniques to wheelchair seat cushions.

Ishihara et al. [64] conducted a computational experiment on interaction with mattress and body trunk. Not only outside of the trunk, but the pressure distribution of the trunk inside (composed of bone, muscle, skin, and fat) is also anatomically estimated. Different physical properties (i.e., hard/soft spring, urethane) of a mattress, deformation of the mattress, and stress concentration of both trunk surface and inside are shown by the Multiple Composite Material Finite Element Method.

6.7. Food technology

Food is an everyday product with a lot of affective implications: there is no doubt that interacting with food, which obviously includes eating, involves our five senses. Ito et al. [65] first introduced a food Kansei model, that was later developed and extended by Ikeda et al. [66]. The food Kansei model, as the general Kansei model, relates technical properties of the food with perceptions conveyed by the food when being eaten.

However, there is a distinction between intrinsic and extrinsic attributes. Intrinsic attributes are related with physical characteristics of the food, such as proportion of ingredients, odour intensity, concentration of volatile components, etc. These intrinsic attributes can usually be measured using devices (gas chromatography for odour intensity, for instance). Extrinsic attributes have no direct relation with the food itself, but appear together with the product: they are related with packaging, visual presentation of the food, etc.

Intrinsic attributes relate to the experience when eating the food, so taste, smell and touch are the implied senses. Extrinsic attributes are connected with the expectations before eating the food, thus vision and – to a lesser extent – hearing are the implied senses.

Food attributes (both intrinsic and extrinsic) are collected based on the technical properties of the food, and correspond to the properties in the general Kansei model. The food Kansei model also uses sensorial descriptors (Kansei words), and the aim of the model is, as usual, connecting the food attributes with the sensorial

perceptions conveyed.

Examples of design of food products can be found in several papers: [67], [68], [69], [70] and [71].

6.8. House interior and garden design

Applying KE to house interior design was one of the earliest significant research areas. There are an enormous number of options for house interior design, and making decisions is very difficult for ordinary people with little experience of this type of activity. The first associated KE research paper was published in 1974 and focused on room colour. Research then evolved to look at other areas, such as interior layouts in 1977, and lighting in 1985 [72].

Although KE is practical in interior design, there are some difficulties. Interior design is a spatial assembly of different components. Making model rooms for Kansei evaluation takes lots of time, space, and budget. Pictures of an existing room are not suitable for Kansei evaluation. The number of variables is too large for mathematical analysis. From the pictures, size and space are not well recognized.

Virtual Reality (VR) is the most promising technology for KE research on housing (and also on buildings more generally). The reasons for recommending VR include:

No limitation with components. Almost any kind of interior and exterior can be designed with 3D Computer Aided Design.

Controlled experiment. Environmental variables such as room size and lights can be controlled.

Spatial recognition. An immersive visual experience of the room space can be achieved with VR.

Humans have a very high ability to recognize texture patterns. Ishihara [61] made an artificial Kansei visual recognition system for wallpaper texture based on CNN (Convolutional Neural Network). Nowadays, lots of applications of CNN are giving substantial improvements in visual cognition systems.

Matsubara et al. [73] made an original 3D Computer Graphics and VR system for KE garden design. Daylight and diurnal shadow variations are important factors for garden design and an original stereo rendering engine was developed for expressing shadow casting. Relationships between trees, garden rocks composition, and Kansei were analysed to good effect.

6.9. Leisure and tourism sector

Although the origins of KE are closely linked to the design of industrial products, the ideas and methodology are now also used in more general contexts. Hartono [74]

incorporated Herzberg's motivator-hygiene (M-H) theory, Kano model, quality function deployment (QFD), Markov chain analysis, and KE analysis methodologies to investigate travelers' expectations of hotel services. It was shown and confirmed that the affective process/Kansei plays an important role in service experiences and was more significant on overall satisfaction than cognitive processes.

In addition to trying to discover how technical properties of a physical product convey certain emotions, KE can be performed with "products" that represent a living experience of leisure or tourism, for example browsing in a department store, attending a concert, or bathing at the beach.

The presentation of these kind of "products", however, is challenging. Creating mock-ups is easier with physical products than with living experiences. The obvious choice for presenting stimuli in this context is completely recreating the experience in real life scenarios, but this can be incredibly expensive to conduct and poses many practical problems for data collection. On the other hand, using common techniques for the assessment of physical products such as presenting photographs (real or computer-created) can narrow the presentation too much. We cannot assume that we capture all the emotional experience of a user when looking at a photograph of a store compared to really shopping in that store. A promising solution is the use of virtual reality (VR). VR can use images and sound to recreate the desired atmosphere, and the participant in the study can move around the scenario and interact with objects in a realistic way [75].

The use of VR in leisure and tourism sector will probably increase in future years, as this technology becomes more easily accessible in both economic terms and friendliness of use.

6.10. Education Counselling and Mindfulness

Every day people are confronted with a myriad of tasks. Their approach to the tasks determines how they feel about them. Mindfulness encourages people to pay attention to everything they do, being aware rather than being on auto-pilot. Goodyear et al. [76] showcase a methodology leading to greater understanding in classroom situations and Elen [77] considers the issue of lack of engagement and how to improve situations. One particular issue in education is disinclination for students to get started on tasks, such as assignments [78]. Procrastination can mean that the task is rushed and/or the tutor is overwhelmed with questions as the deadline

approaches. Kansei research is helping to uncover cues in the assignment that are more beneficial for encouraging a more positive emotional response and lead to less procrastination and a better result.

Kawakita et al. [79] show the potential of VR and avatar-based casual counselling. Their research objectives include exploring the effect of anonymity and confirming so-called embodied cognition which means some environmental factors affect cognition, attitude, and judgments. They also intend to investigate remote and semi-automatic counselling possibilities in this COVID-19 affected stressed world via virtual psychological experiments. This, again, is another fruitful area for further Kansei research.

7. UNIQUENESS OF THE KANSEI APPROACH

Although not being the only methodology aiming to address human emotions, KE is unique in its approach to capture user experience and turning it into product design.

Kansei has a special place in modern research methodology, being highly interdisciplinary and permanently seeking collaborative research and going beyond traditional product design areas. Psychology, Philosophy and other Social Sciences, as well as Management and Business, or many other fields can be brought into Kansei and KE, further enriching it and its scope of applications.

The philosophy is unique because it measures implicit, intangible aspects which are typically unmeasurable. It brings a soft measurement approach resulting in hard measurements. It moves us from vague to concrete. Kansei brings validated scientific methods into the emotional field.

Kansei is embedded in Japanese culture and this concept was made accessible for wider implementation. However, it has required considerable adaptation before it could add value in other cultures, especially in regard to developing the scientific basis of the method including flowcharts and step-by-step guidelines. It could be said that the original Japanese version was analogue, and now a digital approach has been developed for use elsewhere. The new approach develops Kansei from the holistic to a more reductionist approach. This is a response to the fact that Kansei is not intrinsic to non-Japanese thinking and so it has to be carefully described for use elsewhere.

The original Kansei contributes to the fundamentals of affective engineering which is an umbrella including other aspects such as emotional engineering and user experience. Kansei is more than emotions, it is also a

feeling. Kansei is unique as it combines these philosophical aspects with a focused scientific data driven approach.

We note that some gifted designers naturally involve these deeper aspects of design – the uniqueness of Kansei is that it helps more people tap into that aspect of design and do it themselves. This is especially helpful for small and medium enterprises (SMEs) which have fewer more multi-tasked staff as opposed to large organisations who may include several gifted designers in their employ. Kansei links customer needs including hidden needs to product characteristics without intervention of the stakeholders. This is a unique feature; by being inclusive it is possible to trace back design decisions and to understand the reason why they were taken.

Secondly, because Kansei gives a more affective and effective approach to product development, it makes the products stand out from competitors as they are more appealing to the user. Kansei allows this product methodology to be applied more widely to services like healthcare and other sectors such as tourism and hospitality. Kansei incorporates affective elements into the design of products; Kansei Engineering makes Kansei available to the business aspects of organisations including SMEs, which was not so before.

Finally, regarding research collaboration, Kansei provides a unique opportunity for researchers from different specialties to work together and capitalize on the advantage of sharing their eclectic points of view to build new ideas. This is different to other research collaborations because not only do researchers contribute their diverse expertise but this diversity has a synergistic effect of adding to the depth of understanding of each of the experts and hence their contributions, for example the statisticians have to rethink their measurement concepts and the designers reconsider how factors and responses are measured. If this collaborative aspect is well managed it has the potential for creating disruptive technologies and product innovations. Kansei provides a language for communication between different types of specialists. This is so important in the new age where real ground breaking ideas are needed to take advantage of the opportunities offered by Society 5.0 and global pandemics, and to address issues such as climate change; real advances come from disruptive experiences and events.

The concept of a human centred society (Society 5.0) was first proposed in the 5th Science and Technology Basic Plan by the Japanese government as a future society that Japan should aspire to as a follow up to the information society (Society 4.0) [81].

8. REFLECTIONS AND FUTURE TRENDS

The thematic analysis reported in earlier sections indicated that the primary interests of scholars and experts are in KE applications and AI. Future KE applications include 3D computer graphics, security, and artwork. Scholars in AI are investigating topics such as humanistic robotic systems, intelligent agents, and data-driven innovation. KE is also seen as an important component of Society 5.0 because it incorporates humanistic characteristics into products and services, ensuring people's positive experiences and well-being. For instance, Magni et al. (2023)'s work has explored the intersection of emotions and artificial intelligence (AI) in the context of Society 5.0. It emphasizes the importance of understanding and incorporating emotions into AI systems, going beyond the traditional focus on human-machine interaction.

This would facilitate intelligence by addressing people's needs and demands by providing the necessary products and services that fit to the demand. Consumer centricism's anticipated topics include user adaptation, consumer behaviour, and consumer convenience. Scholars also envision KE being used in governance areas such as organisational behaviour, social/workplace wellbeing, and public health. Meanwhile, methodology, modelling, philosophy, automobiles, gerontology, and Kansei Science will be used.

8.1. UX with AR/VR and AI

With the recent commercialization and continuous development of augmented reality and virtual reality (AR/VR) headsets, pairing with other immersion capable multimodal devices, including rendering hi-fidelity haptics, e.g. via wearable gloves and vests, it is quite expectable (Berg & Vance, 2017) that these new technologies can emerge as platforms for UX studies, where physical prototypes are replaced by a similarly realistic experience. The vast potential lies in the flexibility, efficiency, and diversity of experiences, including diverse contexts, that will then be available to researchers to offer to their user panels. In replacement of resource consuming prototypes, a digital experience can allow the users to replicate and modulate the objects of study in a virtual environment, while the experience is still evaluated and felt by real users.

As an illustrative example from the automotive industry (Mahboob et al., 2019), virtual designs for automotive interiors, and many of its possible design variations, can

now be exposed to the user virtually, even allowing them to physically interact with kinematic components and onboard HMIs, while visual and other modality cues are afforded back virtually. In the case of consumer electronics, exploratory research has used similar means, where audible feedback of a computer mouse is conveyed to the user not by the device itself but via headsets and played from a synthesised bank of realistic clicking sounds. This allows researchers to explore desired audible feedback from either pre-recorded or synthesized audio files, even when no real prototype for such sound is available to the researchers. The experience is masked and replaced by a virtual one without any cognitive impairment to the user, i.e. no lag or any conflicting cues.

Furthermore, even the access to users can be made more efficiently, avoiding the usual interview *in situ* and performed partially or entirely remotely. This only requiring that the panel has access to the means required for a virtual platform for the study. In the above example, any user scattered anywhere in the globe that has a computer with internet connection, a mouse and headset can be exposed to the audible feedback available to the researchers, in an interview driven by videoconferencing or any other method made available.

Embedding KE with Artificial Intelligence (Ishihara, S., Masuda, G., Nagamachi, M. & Ishihara, 2015b; Nagamachi, 2017b) and advanced computational methods, such as neural networks and genetic algorithms, has the potential to further enhance the UX not only at an early study design stage but also during the interview and experience itself [45]. Capturing user inputs live, along with their emotional response to an interaction, can allow the design itself to evolve between interviews or even throughout the same session. Aside of the computational effort, exposed virtual prototypes can evolve in an almost resourceless successive generation of design variants according to the user's live positive and negative emotions. Achieving self-adapting designs should further allow focusing or narrowing outcomes from specific design parameters that are of interest to the researchers.

8.2. Envisioning the Future

Kansei is an interesting diverse focus of research effort. Some of the most common aspects have been explored above with examples of past, current and future applications. This review attempts to capture the essence of Kansei but does not claim to cover everything; it is testament to the creativity and vibrancy of Kansei that new ideas are appearing all the time and are welcome in the Kansei community of practice.

Although we are moving towards increased digitization, humans remain at the centre of product design and development. It is vital that the human aspects reflect the full range of human society and in particular the exciting prospect of Society 5.0. For instance, the concept of digital humanism has been introduced as a framework that recognizes the value of human emotions in shaping AI technologies and their impact on society (Magni et al., 2023). The article argues that by considering emotions, AI can better serve human needs, promote well-being, and contribute to a more harmonious and inclusive future. Kansei Engineering offers opportunity to reveal and counteract the tendency for new artificial intelligence to build on the personality and background of the developers. Kansei incorporates ideas from across specialties and across the globe, so it is ideally placed for this task.

In conclusion it is to be hoped that this area of research continues to see collaboration and enthusiasm from serious researchers and practitioners from around the world bringing their unique contributions to the Kansei community and encouraging productive partnerships between academia and industry.

The thematic analysis of the KEER conference series has also included future outlook from the respondents on the emerging research areas involving Kansei and emotion. The result shows that the main interests of scholars and experts are in the KE application and AI. Topics such as 3D computer graphics, security, and artwork are of interest in the Future KE application. In AI, scholars are exploring themes such as humanistic robotic systems, intelligent agents, and data-driven innovation. We also note that Kansei is an important part of the drive for Society 5.0 since it introduces humanistic characteristics into products and services, ensuring people's positive perception and well-being. This would facilitate intelligence in the sense that people's needs and demands will be addressed by offering necessary products and services in the appropriate forms and amounts. Projected topics in consumer centricism include user adaptation, consumer behaviour, and consumer convenience. Scholars also anticipate the implementation of KE in governance areas, such as in organizational behaviour, social / workplace wellbeing, and public health. Meanwhile, methodology, modelling, philosophy, automobile, gerontology, and Kansei Science will also be in play.

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