Ergonomics

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/terg20

A model-driven approach for prospective ergonomics: application to ikigai robotics

Stéphanie Buisine, Mégane Sartore, Ioana Ocnarescu & Louis-Romain Joly

To cite this article: Stéphanie Buisine, Mégane Sartore, Ioana Ocnarescu & Louis-Romain Joly (19 Oct 2024): A model-driven approach for prospective ergonomics: application to ikigai robotics, Ergonomics, DOI: 10.1080/00140139.2024.2418960

To link to this article: https://doi.org/10.1080/00140139.2024.2418960

Published online: 19 Oct 2024.

ERGONOMICS
https://doi.org/10.1080/00140139.2024.2418960

Taylor & Francis
Taylor & Francis Group

RESEARCH ARTICLE

A model-driven approach for prospective ergonomics: application to ikigai robotics

Stéphanie Buisine[a], Mégane Sartore[a,b], Ioana Ocnarescu[c] and Louis-Romain Joly[b]

[a]CESI-LINEACT, Nanterre, France; [b]SNCF, Paris, France; [c]Strate Research, Sèvres, France

ABSTRACT

Prospective Ergonomics requires building a vision of the future, which can be achieved empirically (e.g. analysing unmet needs) and/or creatively (e.g. creating future needs). We develop an alternative way of imagining the future, through a model-driven approach. Based on several developmental models, we provide a global picture of possible future(s) emphasising higher-ordered motivations and values (e.g. meaningfulness, accomplishment). To implement them, we then present a model of human accomplishment reinterpreting the concept of ikigai in light of selected psychological theories (e.g. self-determination, eudaemonic well-being, mindfulness). Finally, we apply it to an Industry 5.0 case study named ikigai robotics: we designed an equipment for railway maintenance following a double design process – a functional design loop and a motivational design loop. The process proved inspirational and the results both original and promising, opening avenues for Prospective Ergonomics to develop a new approach for designing the future.

PRACTITIONER SUMMARY: We provide a conceptual framework for Prospective Ergonomics and a case study exemplifying how motivational needs can be diagnosed and addressed in a design process. Psychological needs (self-fulfilment, meaningfulness) come as a new layer in addition to productivity needs (usability) and physiological needs (occupational health and safety).

ARTICLE HISTORY
Received 6 October 2023
Accepted 15 October 2024

KEYWORDS
Development; ikigai; self-determination; relatedness; mindfulness

1. Imagining the future

Prospective ergonomics aims to contribute to designing products, systems and services likely to meet future human needs (see Robert and Brangier 2024). This challenge raises many methodological issues such as: how to anticipate future users, future needs and expectations, future values and activities, future technology and artefacts, or future organisation modes (Robert and Brangier 2024)? Imagining the future also involves antagonistic mechanisms: on the one hand, a prospective approach requires projecting into a long-term and high-level perspective (Ratcliffe 2006; Godet and Roubelat 1996) breaking away from the present; on the other hand, predicting or forecasting the future often builds on the present or the past (e.g. weak signals, trends analysis). Consistently, three paradigms were identified for structuring a need-seeker innovation strategy (Buisine, Taton, and Boisadan 2021): discovering future needs (which builds on the present), recovering fundamental needs (which builds on the past), and creating needs. The latter one is a pure creative approach promoting a free-rider mode, disregarding constraints. However, even in this mindset, imagining the future may be influenced by present or past experiences and knowledge: at a neurophysiological level, it was shown that imagining the future activates the same brain areas as past recollection (Arzy et al. 2009). Researchers and practitioners willing to implement prospective ergonomics may still lack a conceptual and methodological framework to imagine the future.

Our research aims to provide a model-driven approach for prospective ergonomics to expand designers' toolbox in addition to existing empirical and creative approaches. We will successively present a developmental model and a cognitive model of human accomplishment, and then show how we applied them to the design of an industrial equipment. A model-driven approach may both support divergent thinking in imagining the future (as it helps to break away from the present and avoid design fixations) and support convergent thinking (by avoiding overwhelming divergence

CONTACT Stéphanie Buisine sbuisine@cesi.fr CESI-LINEACT, 93 boulevard de la Seine, 92000 Nanterre, France

resulting from creative free riding). Moreover, a model-driven approach may enable designers and ergonomists to give an intention (e.g. ethical, strategical, sustainable) when designing the future. In the following sections, we first present developmental frameworks structuring a vision of the future, then a cognitive model supporting the implementation of such a vision, and finally a case study named 'Ikigai Robotics' in railway maintenance application field.

2. Developmental models of humans and society

Developmental models provide guidance to anticipate how future users may view the world, what their needs and expectations might be in the future, and what solutions may meet their needs. Several models are based on an analogy between the development of individuals' consciousness along the lifetime (psychogenesis) and the development of societies' consciousness along the history of mankind (sociogenesis). Both processes are seen as building on successive value systems and worldviews which arise in response to solving problems of the previous system. For example, several theories of human development (Graves 1970; Beck and Cowan 2014; Wilber 2001) model individual psychological growth during lifetime through an alternation of individualist and collectivist stages progressing from the satisfaction of physiological needs in early childhood (e.g. survival, security) towards the satisfaction of highest psychological needs in late life (e.g. fulfilment, holistic view). The same may apply to the development of human organisations (Wilber 2001; Laloux 2014).

According to a recent model (Laloux 2014), the two dominant stages of development of today's organisations are labelled Amber and Orange. The Amber stage (represented in e.g. administrations, military, religious and political organisations) is collectivist and arose with the agricultural revolution. It relies on enormous organisations embracing long-term and ambitious projects such as building pyramids or cathedrals. Amber sociotechnical systems emphasise values such as: conformity, quality, rigour, stability, security.

The subsequent stage, labelled Orange, appeared with the industrial revolution. It is a more individualistic stage, with meritocracy and innovation as core values, and materialistic motivations (social and economic growth). Its sociotechnical systems emphasise competitivity and productivity. This stage represents the current level of maturity of mankind and is still the dominant paradigm in profit organisations and multinationals. However, it may have reached its limits today with excessive financialisation, inequality increase and climate change. As these challenges may not be solvable in the paradigm which created them, human organisations may evolve to new stage(s). The Green stage following Orange arose with the digital revolution and is characterised by a deeper focus on values and a more systematic involvement of stakeholders. Its sociotechnical systems support e.g. large-scale collaboration and agility.

Finally, the Teal stage is characterised by a self-determined evolutionary Purpose transcending economic concerns to achieve a positive impact on the world. Its philosophy echoes popular stereotypes regarding young generations (Mehra and Nickerson 2019; Mahmoud et al. 2020), which give more prominence to well-being and intrinsically motivating jobs matching their personal values. However, the very concept of generation is still questionable, and large-scale analyses support the hypothesis of the context impacting similarly all age cohorts more likely than the hypothesis of a differential impact on cohorts (Cucina et al. 2018; Rudolph et al. 2021). Hence the tendency to expect an intrinsically motivating job may concern the entire contemporary workforce, and not only younger ones.

This global and massive evolution is in line with Inglehart's seminal work on cultural and political change in post-industrial democracies through modernisation and post modernisation (Inglehart 2020; Inglehart and Baker 2000): when economic security is satisfied, basic political priorities naturally shift towards post materialism (e.g. rational, tolerant and participatory values) and the fulfilment of individual psychological needs (e.g. well-being, intellectual life, relatedness, aesthetics). Societies are climbing the 'freedom ladder' (Welzel 2014) up to individual empowerment, which is modelled as a universalist self-driven automatism by which human mind adjusts to its existential condition (Beugelsdijk and Welzel 2018).

These principles of modernisation and universalism may be challenged by a multipolar, post-liberal world order (Bettiza and Lewis 2020; Todorović 2022) and the revival of authoritarian regimes (Gat et al. 2009). Nondemocratic great powers such as Russia and China provide an ideological counterbalancing by contesting liberal norms and supporting 'illiberal' values such as tradition, hierarchy and community (Bettiza and Lewis 2020). If alternative worldviews remain desirable (in particular, the following section will address individualist and collectivist cultures), nondemocratic powers may not represent the far future, as they rely on internal tensions (e.g. corruption, poverty, illiteracy) which are costly to maintain (e.g. knowledge blocking, repression of pro-democratic forces, Inglehart and Welzel 2010) and make them prone to implosion (Gat et al.

2009). Overall, despite the succession of surges and declines, the growing emphasis on well-being and self-expression is attested by time series data from values surveys worldwide, suggesting that freedom and autonomy could well represent universal aspirations (Inglehart and Welzel 2010).

In sum, several developmental models focusing on individual, organisational, and cultural change are congruent in suggesting that human aspirations evolve towards higher-ordered motivational needs (e.g. purpose, meaningfulness, relatedness) and post-materialistic values (e.g. autonomy, sustainability). Prospective ergonomics could play a role in supporting the evolution of products and systems towards these aspirations. In addition to stability and security (Amber values), to productivity and efficiency (Orange values), to participation and agility (Green values), technology of the future should also be fulfilling, support individual and collective accomplishment towards a positive impact on the world (Teal values). The developmental models of humans and society provide us with a main orientation but to operationalise this vision we now need a model of human accomplishment: in the following section, we present a cognitive model of 'Ikigai' (purpose in life) in the workplace.

3. A cognitive model of human accomplishment

The question of accomplishment is not straightforward and depends on when and where you live. For example, meaningfulness at work was not a subject of interest until the 1980s (Bernaud et al. 2020), i.e. very recently in the history. This is consistent with the abovementioned development of consciousness in societies (Davies and Buisine 2024): when individuals had no freedom of choice for their lives, fates and occupations (i.e. social determinism), the very notion of motivation was irrelevant and questioning the meaning of life could even have been counterproductive for survival. Nowadays, the notion of accomplishment also depends on your cultural background: in a collectivist worldview, individuals have to fit into societies, while in individualist cultures, the aim of society is to promote individual well-being (Oyserman and Lee 2008). Consistently, East Asian people value interdependence (to friends and family), whereas North Americans value independence. Cultures also have different definitions of achievement: collectivist cultures value one's contribution to the group (Markus and Kitayama 1991) while individualist cultures focus on personal needs and desires and value individual accomplishment (Deci and Ryan 2000).

To offer the broadest approach to human accomplishment, we develop a model attempting to integrate both worldviews: starting from a Japanese philosophy of life (ikigai), through its American interpretation, to a proposal bridging the gap with theoretical frameworks of self-determination and eudaemonic well-being, among others.

Ikigai is a Japanese concept referring to a sense of 'life worth living' (Kotera et al. 2021), encompassing well-being, purpose in life or reason for living (Mathews 1996). Having found one's ikigai is said to improve health (Nakanishi 1999) and longevity (Sone et al. 2008; Tanno et al. 2009) by reducing risks of all-cause mortality. Ikigai was made popular in North America in the form of Winn's diagram (Figure 1, Sartore et al. 2023), which is particularly inspiring because it articulates personal factors ('what I love' and 'what I am qualified for') and external rewards ('what I am paid for') to altruistic purposes ('what the world needs'). The conceptual interpretation of ikigai through scholarly literature emphasises three main building blocks (Sartore et al. 2023): Self-determination theory (Deci and Ryan 2000), Mindfulness (Ryan, Huta, and Deci 2008) and eudaemonic well-being (Seligman 2018).

Self-determination theory sets the existence of three universal psychological needs: competence (feeling efficient and mastering one's environment), autonomy (being agent of one's own behaviour), and relatedness (experiencing meaningful connections with other people). The motivational process sets the individual in motion towards satisfying these needs. The theory contrasts intrinsic and extrinsic motivation (Deci and Ryan 2000), notably in a work context (Deci, Olafsen, and Ryan 2017; Gagné and Deci 2005), along

Figure 1. Winn's diagram of Ikigai adapted by Sartore et al. (2023).[1]

a continuum: extrinsic motivation (obtaining rewards and avoiding punishment), introjected motivation (seeking internal consequences such as self-esteem or pride and avoiding guilt or shame), identified motivation (identifying with the perceived value of a behaviour), up to intrinsic motivation (performing activities for their own sake). The pleasure associated to intrinsic motivation comes from the satisfaction of one or several psychological needs (competence, autonomy, relatedness).

In Winn's diagram of ikigai, 'what I love' refers to intrinsic regulation, 'what I am paid for' to extrinsic regulation, 'what I am qualified for' to introjected regulation and 'what the world needs' to identified regulation. However, there is an important difference between self-determination theory and ikigai: consistent to an individualist approach, self-determination theory focuses on personal growth and intrinsic motivation as the ultimate achievement. Consistently, it was stressed that competitive individualism and capitalistic societies may hinder altruism and prosocial purposes, as well as lead to unsustainable attitudes and behaviours (Ryan, Huta, and Deci 2008). In a more collectivist approach, ikigai places meaningfulness, usefulness, and altruistic goals above intrinsic pleasure and satisfaction. The 'What the world needs' area may therefore bring most of the inspirational power of Winn's diagram, because this idea of achieving something greater than one's own pleasure (self-transcendence) questions life/work purpose.

Self-transcendence requires awareness of what is worth doing, the desire to make meaningful choices and align to one's values. Mindfulness is an attentional process characterised by an open and receptive processing of both internal and external events (Ryan, Huta, and Deci 2008). It includes self-awareness, which is linked to the satisfaction of the need for autonomy (Gagné et al. 2022), and the ability to feel and experience what is meaningful in life. As such, it is central to eudaimonia or psychological well-being.

Models of well-being distinguish hedonic vs. eudaemonic well-being: hedonism relates to short-term affects and satisfaction (Diener 1984), i.e. how one feels at the moment, while eudaemonic well-being relates to long-term life experiences (Ryan and Deci 2001) such as personal growth and purpose in life. Both from a linguistic and a conceptual viewpoint, ikigai appears closer to eudaemonic well-being (Kumano 2006). To achieve eudaemonic well-being in the long-term, one may have to overcome hedonic well-being in the short term (e.g. make efforts, fail, endure and try again). PERMA is a framework of the building blocks of well-being (Seligman 2018) likely to cover both hedonic and eudaemonic dimensions: Positive emotions (feeling joyful), Engagement (interest and absorption in the task), positive Relationships (satisfaction with one's social relationships), Meaning (the belief that one's life is valuable and connected to something greater), and Accomplishment (making progress, experiencing self-esteem and sense of achievement). Positive emotions and Engagement mainly generate hedonic well-being, Meaning and Accomplishment mainly generate eudaemonic well-being and Relationships may contribute to both.

In sum, ikigai provides a framework extending self-determination theory and satisfaction of psychological needs (competence, autonomy, relatedness), by highlighting meaningfulness and eudaemonic well-being as desirable outcomes, beyond pleasure and hedonic well-being.

Although technological change can have a major impact on people's motivation and well-being at work, these impacts are rarely taken into account in the design process (Gagné et al. 2022). Some authors have introduced the notion of motivational design to improve technology (Szalma 2014) or work design (Gagné et al. 2022). In both cases, self-determination theory leads to focus on intrinsic motivation and psychological needs (competence, autonomy and relatedness). Our approach through ikigai extends the focus to identified motivation, which refers to meaningfulness at work, and is included neither in intrinsic motivation nor in basic psychological needs. Meta-analytic results indicate that intrinsic motivation is the most important for employee well-being, yet identified motivation is more powerful in predicting performance and organisational citizenship (Van den Broeck et al. 2021). Sensemaking is also an important issue by itself, in particular in case of 'career shocks' that can be caused by crisis or similar disruptive events including technological change (Gagné et al. 2022).

Furthermore, ikigai encompasses the work sphere as a whole. In contrast, motivational design focuses on Human-Machine Interaction (Szalma 2014; Passalacqua et al. 2024): it aims to support motivation to use technology ('I like to perform this activity with this tool'), while we aim to support motivation to work ('I like my job'). Research on motivation to use the technology highlights that "intrinsic motivation may not be a realistic goal for many applications" (Szalma 2014, p. 1458). In contrast, our aim is to study intrinsic and identified work motivation, and infer how technology can contribute thereto.

This could shape the project of prospective ergonomics: future products and technology should stimulate intrinsic motivation (contribute to meeting needs

for competence, autonomy and/or relatedness), stimulate identified motivation (raising awareness to higher-ordered purposes and values), and generate eudaemonic well-being. Consistent to a developmental approach, this new layer of system requirements arrives in complement (and not in replacement) of previous layers dealing with security or efficiency.

In the following section, we present a case study in which we applied ikigai framework to the design of an industrial tool for railway maintenance: in addition to specifying functional needs (e.g. safety, usability, productivity), we put a special emphasis on workers' motivational needs in order to increase their sense of purpose and eudaemonic well-being. We were in an exploratory rather than a confirmatory approach and had no a priori hypothesis either on maintenance worker's ikigai, on the methodological approach that was implemented in a constructivist way, or on the solutions to develop. We named this case study ikigai robotics.

4. Application to ikigai robotics

The fourth industrial revolution introduced advanced technologies like artificial intelligence, bio- and nanotechnology, quantum computing and robotics in the production process (Neumann et al. 2021). In Industry 4.0, humans become Operators 4.0 with enhanced perceptive, cognitive, motor, collaborative and social capacities (Kaasinen et al. 2020). The operator is not fully separable from technological artefacts, entering a human-automation symbiosis for enhancing workforce capabilities (Rauch, Linder, and Dallasega 2020).

Industry 4.0 also brings employment issues (e.g. threats of robots replacing humans and leading to massive job losses) and questions the future of work (Görmüş 2019). Introducing robots for increasing performance may result in a decrease in human engagement (Molino, Cortese, and Ghislieri 2020) and a loss of meaning. Industrial revolutions pushed operators farther and farther away from the product (Fourquet-Mahéo et al. 2019): while the artisan is in direct contact with the product and the customer, the operator in a production line is in contact with the machinery and indirectly with the product. In Industry 4.0, the operator controls the robot, which is in contact with the machinery, which produces the product, which one day attains to the customer. Operators may spend their worktime only with a vague notion of their customers, their needs, the purpose they serve and ultimately the meaning of their job.

Industry 5.0 was launched to overcome the limitations of Industry 4.0, acknowledged as mainly technocentric (Neumann et al. 2021; Passalacqua et al. 2024; Kadir, Broberg, and Souza da Conceição 2019) and based on economic thinking (Dixon-Declève et al. 2022). Industry 5.0 implements human-centricity, sustainability, and resiliency to align with social values (Passalacqua et al. 2024), inclusion, and workers' well-being (Dixon-Declève et al. 2022). Consistent to Industry 5.0, ikigai robots (Sartore et al. 2022) aim to increase operators' intrinsic and identified motivation, meet their needs for competence, autonomy and relatedness, highlight their contribution to the company's purpose (values) and to a positive impact on the world (meaningfulness).

4.1. Industrial context

To test the relevance of our prospective approach, we implemented the ikigai framework in the field of railway maintenance and participated in the design of a powered tool for train roof inspection. Roof inspection is a routine maintenance operation aimed is to check the pantograph head (the part in contact with the catenary, thereby highly subject to wear). Pantograph heads generate the second highest maintenance cost in trains after the axles. Their inspection can be performed in the technical centre but there is also a need for a mobile equipment enabling intervention teams to inspect train roof in situ, and safely (risk of electric shock with the catenary, risk of falling).

To design a prototype in the framework of ikigai robotics, we ran two parallel design loops: A *functional* design loop in a participatory mode with end users, and a *motivational* design loop in which we generated solutions for supporting operators' ikigai.

4.2. Functional design loop

The inspection tool takes the form of a mobile deployable probe in bistable material equipped with an augmented reality device sending images and digital measurements of the pantograph in real time to operators on the ground.

The functional design loop was based on a classical User eXperience approach (Lallemand and Gronier 2018) iterating around exploration, ideation, generation and evaluation steps. This part of the project focused on:

- Safety of use in particular with regard to electric risk due to the catenary,
- Easiness of conveying the inspection tool to the site of intervention,
- Speed and easiness of installation on the train,
- Accuracy of data collected (visual diagnosis and measurements of the pantograph head).

Three end-users and their manager participated in the design process. We conducted field observations to analyse the activity of pantograph inspection at the technical centre. Insights were gathered in the form of an experience map including each step of the inspection journey, which were validated by end-users. User tests of a first prototype enabled us to collect requirements on robustness, weather resistance, installation and measurement options, protection during transportation and storage. An ideation phase led to 28 different concepts for conveying, installing and deinstalling the tool. They were evaluated by end-users, and convergence was achieved by codesign. Finally, functional solutions were iteratively refined through three rounds of prototyping and user tests.

4.3. Motivational design loop

The search for motivational solutions to be integrated into the inspection tool was separated from the functional design loop, because end-users gave them a very different status: as they did not catch the relevance of motivational solutions, they were not engaged in their design. We conducted this part of the process in a transformational instead of a participatory mode: building on a leading vision and pushing solutions to test instead of making them emerge from the field.

4.3.1. First-step ikigai diagnosis

We needed to characterise the ikigai of railway maintenance operators: their current state of self-determination, mindfulness and eudaemonic well-being, meaningfulness, the mechanisms underlying their feeling of accomplishment, and the role of technology therein. To this aim, we used a survey study, as described below. We are aware of the limitations of this study, which was not conducted under controlled laboratory conditions, and consider that these results should be taken with caution and may under no circumstances be generalised. However, we also consider them as insightful for gaining new knowledge on users, in the aim to innovate for them and develop a new prospective approach.

4.3.1.1. Participants. The first survey round was designed for general maintenance staff, which represents a parent population of about 50,000 agents. We targeted teams with specific technological environments: teams using advanced technology (e.g. drones, robot, smart glasses, exoskeleton) and teams using more traditional technology for the same maintenance operations. About 400 agents were contacted via their managers. We collected answers from 46 participants (11.7% response rate) who were 93% men, and mainly technicians. N = 21 participants belonged to the Advanced technology group and N = 25 participants to the Traditional technology group.

4.3.1.2. Material. We built a survey questionnaire to investigate ikigai using scales from the literature (Table 1) with 5-point Likert-type scales.

4.3.1.3. Procedure. The survey was circulated by managers in their teams. Participants could take the online or paper version at their convenience. The survey had been pre-tested to take about 25 min to answer, including the consent form.

4.3.1.4. Results. We verified that our theoretical construct of ikigai (i.e. Work motivation, Meaningfulness, Engagement and Eudaemonic well-being) was statistically reliable (Cronbach's α = .788). Once aggregated, the measure reveals a medium-to-high level of ikigai among

Table 1. Structure of the survey. Ikigai construct was measured by aggregation of factors marked (*).

Ikigai factors	Definition	Scales	Example items
*Work motivation	Intraindividual force explaining one's behaviour, along a continuum from extrinsic (rewards and punishment) to intrinsic motivation (pleasure).	Gagné et al. (2015)	Extrinsic: 'I risk losing my job if I don't put enough effort in it.' Intrinsic: 'The work I do is interesting.'
Psychological needs	Competence: mastering one's environment. Autonomy: being agent of one's behaviour. Relatedness: experiencing meaningful connections with others.	Gillet et al. (2012); Van den Broeck et al. (2010)	Competence: 'I feel competent at my job.' Autonomy: 'I feel free to do my job the way I think it could best be done.' Relatedness: 'At work, I feel part of a group.'
Mindfulness	Attentional process open and receptive to both internal and external events.	Baer et al. (2008)	'I rush through activities without being really attentive to them.'
*Meaningfulness	Feeling of being valuable and connected to something greater.	Steger, Dik, and Duffy (2012)	'My work makes me make sense of the world around me.'
*Eudaemonic well-being	Long-term life experience related to personal growth.	Kern et al. (2015)	'I am making progress towards accomplishing my work-related goals.'
*Engagement	Positive state characterised by vigour, dedication and absorption.	Schaufeli et al. (2002)	'When I get up in the morning, I feel like going to work.'
User eXperience with work tools	Affective, cognitive and behavioural dimensions of interaction with a product.	Lallemand and Koenig (2017)	'With the help of *(tool)*, I will achieve my goals.'
Career development	Evolution of one's job, role or team.	Wioland, Debay, and Atain-Kouadio (2019)	'Since I work with *(tool)*, my job title was changed.'

our respondents (M = 3.63 on a 5-point Likert-type scale, SD = .47).

To identify ikigai drivers, we used the aggregated measure as dependent variable and performed a multiple regression analysis, which highlighted three significant predictors: satisfaction of the need for relatedness (β = .484, t = 3.499, p = .001), User eXperience with work tools (β = .499, t = 3.067, p = .004) and career development (β = .557, t = 3.750, p = .001).

To investigate whether technology has an impact on ikigai, we also performed a series of analyses of variances contrasting the groups using advanced vs. traditional technology. Advanced technology proved to have a positive impact on User eXperience ($F(1,41) = 10.412$, $p = .002$, $\eta^2p = .203$), work engagement ($F(1,41) = 4.213$, $p = .047$, $\eta^2p = .093$), alignment with corporate values (which is part of meaningfulness, $F(1,41) = 4.213$, $p = .045$, $\eta^2p = .094$) and performance (which is part of eudaemonic well-being, $F(1,41) = 5.906$, $p = .020$, $\eta^2p = .126$).

4.3.1.5. Discussion. For our design project, we can build on the following insights: advanced technological solutions may be a good driver of ikigai in our application field, as they are likely to support engagement and performance while remaining aligned to corporate values and culture. A good User eXperience is key to nurture ikigai. Finally, the most original and inspirational insight deals with the need for relatedness: our search for ikigai drivers for maintenance operators emphasised relatedness as a significant positive predictor of ikigai. This provides evidence for an implicit but strong contextual factor of railway maintenance: its genuinely social and collectivist nature. Integrating this dimension into the design of future technology is at the same time meaningful (because everyone knowing the company is aware of this cultural trait), highly original (at least in Industry 5.0, viewing robotic solutions as part of a collectivist system, or integrating them into an organisational community, is infrequent) and challenging (as nothing in the functional design loop relates to a social or collective dimension). Coactive design based on teaming requirements (Johnson et al. 2014, Johnson, Vignati, and Duran 2018) promotes the design of robots as interdependent teammates likely to engage in opportunistic relationships with humans (e.g. helpful behaviour, warning, observations). We may build on such approach to stimulate relatedness, and, consistent with ikigai, further extend it to meaningfulness, social identity, sense of belonging and so on.

4.3.2. Second-step ikigai diagnosis

4.3.2.1. Participants. We performed a second survey round restricted to end-users, i.e. maintenance operators concerned with train roof inspection in the specific technical centre which participated in the functional design loop. N = 8 operators took the survey.

4.3.2.2. Material and procedure

A shorter version of the previous survey was used because we had a limited time with operators (only 15 min dedicated to the survey). We circulated a paper version during the kick-off meeting of the design project.

4.3.2.3. Results and discussion

We investigated the drivers of ikigai (α = .738) and obtained a different pattern of results in this group: here the positive predictors of ikigai were autonomy (β = .611, t = 21.188, p = .030) and mindfulness (β = .849, t = 18.199, p = .035) whereas relatedness appeared to be a negative predictor of ikigai (β = −.675, t = 19.866, p = .032). Although it was puzzling to find relatedness as a driver of ikigai for generic maintenance staff and a barrier to ikigai for end-users, we decided to keep this paradox in the design process and integrated Singularity as a new potential driver of ikigai corresponding to the opposite of relatedness. In the remainder of the design process, we defined singularity as 'the feeling of being unique'. Thereby, it also refers to an individualistic viewpoint while relatedness refers to the collectivist culture of the company, but both are interesting in a prospective approach open to several possible cultural changes.

This double ikigai diagnosis resulted in the decision to focus on four insights for the motivational design loop: integrating into the inspection tool solutions supporting relatedness, autonomy, mindfulness and singularity.

4.3.3. Ideation/generation/evaluation of solutions

The following step consisted in generating ideas responding to the motivational design brief. We implemented several creativity workshops with the multidisciplinary design team as well as Design students. As previously mentioned, we did not run the ideation phase with end-users, as motivational solutions seemed too abstract to them and too far away from their daily concerns. The diverging phase resulted in several hundreds of ideas, which we iteratively sorted, combined and evaluated to converge on 17 concepts.

Examples of ideas include:

- Mindfulness: the inspection tool is capable of detecting a danger (e.g. train approaching, meteorological trouble, problem with the catenary) and alerting maintenance operators; the inspection tool augments operators' senses and feeling

(sight, touch, hearing, perception, emotion…); the tool makes operators aware of their impact on the world (e.g. *This pantograph will be able to run xxx km with xxx passengers and save xxx tons of carbon; This month you have inspected xxx pantographs, which represents xxx passengers*).

- Relatedness: the inspection tool leaves a tag on the train for fellow maintenance teams and train drivers (e.g. *This locomotive was maintained by Xxx*); the inspection tool warns her user when another operator/intervention team needs help for whatever reason; possibility to geolocate the tool; the tool wears social identity cues (e.g. team or company logo).
- Singularity: being able to customise one's inspection tool, giving her a name and lifelike (e.g. animal) features; the tool is equipped with an ID card for security protocol like her fellow human operators; 'living' tool which knows her team-mates, learns, and evolves over time.
- Autonomy: the inspection tool promotes operators' expertise (humans can validate, fix, re-do, complete the tool's measurements); the inspection could be performed by a single operator with his partner tool (instead of two operators + the tool).

The selected ideas were presented to end-users in the form of storyboards. Almost all ideas were approved although they were previously reluctant to discuss motivational issues, considering them as pointless with regard to functional issues. Their evaluations gave pre-eminence to solutions supporting mindfulness, then equally singularity and relatedness. Autonomy was less supported, but we cannot decide whether it is due to a lack of relevant solutions in our proposals, or to a less desirable driver to ikigai.

4.4. Conclusion of the case study

The aim of this study was to upgrade technology for railway maintenance in the spirit of Industry 5.0, i.e. integrate advanced technology and design it for human engagement. To meet performance during train roof inspection onsite while supporting operators' self-determination and meaningfulness, we conducted two parallel design loops: one dedicated to functional solutions, and one focusing on motivational solutions. The originality of the study lies in the latter process: to achieve the design and validation of motivational solutions for railway maintenance operators, we first studied their ikigai profile. This step revealed interesting and equivocal insights highlighting four potential drivers to ikigai: satisfaction of the needs for relatedness, autonomy, singularity (defined here as an individualistic opposite to relatedness), and mindfulness.

We consider that the design of motivational solutions for Industry 5.0 fully complies with the aims of prospective ergonomics, namely to design systems meeting future human needs. The need for fulfilment is likely to be more and more expressed by current workers, and most importantly by future workers. In this study, this need was neither expressed nor conscientized by end-users, who felt free to tell us that the only solutions making sense for them were functional solutions. For this reason, we did not follow a participatory design approach and studied ikigai through psychometric and statistical means, because we may have had no answer to an explicit questioning such as 'What makes your job fulfilling? How to increase your feeling of accomplishment at work?' and so on. At the current stage of development of human consciousness, such mechanisms remain largely implicit. This is also why we ran the ideation phase offstage with experts and students. However, once the solutions storyboarded, end-users found them useful (not essential, but at least desirable). The lesson to draw from this research for prospective ergonomics relies on this motivational design loop.

The remaining question relates to the real impact of these motivational solutions on operators' ikigai. We currently have no answer to this issue, for two main reasons. Firstly, a design project is insufficient to conclude: we should instead run a controlled experiment contrasting the use of two versions of the inspection tool (with and without motivational solutions) in matched groups of maintenance operators for a sufficient amount of time (at least several months) to measure an impact on ikigai, i.e. on self-determination, eudaemonic well-being, sense of purpose and so on. The second and more theoretical reason is that by nature, prospective solutions should be fairly evaluated only in the future: whether a prospective solution would be invalidated today does not mean that it would not be validated in the future. Innovation literature is full of examples of disruptive solutions which were rejected in a short term, then resulted in the creation of new paradigms (Christensen 2013). Time will tell whether our innovative inspection tool for pantographs inspired from ikigai robotics will pay off in terms of industrial performance and operators' ikigai.

5. Conclusion

As its mother discipline Ergonomics, Prospective Ergonomics is mainly rooted in an empirical approach, based on activity analysis, situated/grounded

observations and a deep understanding of the context of use/work. This paradigm enables ergonomists to inspire future products and systems on the basis of unmet needs. To further imagine the future, creative approaches bring invaluable benefits to prospective ergonomics, but also bear a few limits: the implicit interference of present and past knowledge (i.e. design fixation), and the risk of irrelevancy, as purely creative ideas sometimes have no foundation.

Our aim was to promote a model-driven approach for prospective ergonomics to support a vision of the future including potential societal shifts and reduce the risk of unsuccessful ideas. We described several developmental models of humans and society, offering a consistent perspective on the future, towards higher-ordered motivational needs and post-materialistic values. Our general recommendation for Prospective Ergonomics would then be to focus on this overarching goal and contribute to designing products, systems and services compliant to such needs and values. To implement this vision, we developed a cognitive model of human accomplishment, based on scholarly literature on self-determination and eudaemonic well-being, including engagement, relatedness, and meaningfulness. This model also supports self-transcendence and awareness to prosocial and sustainable values. We provided a case study illustrating how a railway maintenance equipment could become a medium to meet motivational needs (in addition to achieving its functional purpose, of course).

In terms of working climate, well-being and attractiveness, ikigai technology and systems alike seem desirable and useful. However, from a pure economic viewpoint and considering market competition, they may be viewed as futile. Most of the population, in particular contemporary executives, may believe that such concerns are inappropriate in today's capitalistic world, with continuous financial pressure. In this respect, the developmental models we presented lead us to expect that such initiatives, although marginal today, represent the future of the workplace, and are consistent with the sociocognitive development of mankind.

Note

1. From a geometrical viewpoint, this representation is incorrect (some intersections are not visible, e.g. 'What I love' with 'What I am paid for', excluding the 2 other areas). For this reason, we discuss only the 4 areas and do not develop the intersections' conceptual meaning.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Ethical statement

All participants gave their informed consent for inclusion before they participated in the case study. The study was conducted in accordance with the requirements of the Office Français de l'Intégrité Scientifique to which the main investigators' institution has adhered.

Funding

This work was supported by ANRT CIFRE grant # 2020-0203 and conducted as part of Robotics by Design Lab https://www.roboticslab.design/.

References

Arzy, S., S. Collette, S. Ionta, E. Fornari, and O. Blanke. 2009. "Subjective Mental Time: The Functional Architecture of Projecting the Self to past and Future." *The European Journal of Neuroscience* 30 (10): 2009–2017. doi:10.1111/j.1460-9568.2009.06974.x.

Baer, R. A., G. T. Smith, E. Lykins, D. Button, J. Krietemeyer, S. Sauer, E. Walsh, D. Duggan, and J. M. G. Williams. 2008. "Construct Validity of the Five Facet Mindfulness Questionnaire in Meditating and Nonmeditating Samples." *Assessment* 15 (3): 329–342. doi:10.1177/1073191107313003.

Beck, D. E., and C. C. Cowan. 2014. *Spiral Dynamics: Mastering Values, Leadership and Change*. Oxford:John Wiley & Sons.

Bernaud, J. L., L. Lhotellier, L. Sovet, C. Arnoux-Nicolas, and F. Pelayo. 2020. *Psychologie de l'accompagnement-2e éd.: Concepts et outils pour développer le sens de la vie et du travail*. Paris: Dunod.

Bettiza, G., and D. Lewis. 2020. "Authoritarian Powers and Norm Contestation in the Liberal International Order: Theorizing the Power Politics of Ideas and Identity." *Journal of Global Security Studies* 5 (4): 559–577. doi:10.1093/jogss/ogz075.

Beugelsdijk, S., and C. Welzel. 2018. "Dimensions and Dynamics of National Culture: Synthesizing Hofstede with Inglehart." *Journal of Cross-Cultural Psychology* 49 (10): 1469–1505. doi:10.1177/0022022118798505.

Buisine, S., A. Taton, and A. Boisadan. 2021. "Need-Seeking: Creating, Discovering or Recovering Needs?" In*Proceedings of IEA 2021 Triennal Congress of the International Ergonomics Association, LNNS*, edited by N. L. Black, Vol. 219, 624–630. Berlin: Springer.

Christensen, C. M. 2013. *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*. Brighton (MA): Harvard Business Review Press.

Cucina, J.M., K.A. Byle, N.R. Martin, S.T. Peyton, and I.F. Gast. 2018. "Generational Differences in Workplace Attitudes and Job Satisfaction: Lack of Sizable Differences across Cohorts." *Journal of Managerial Psychology* 33 (3): 246–264. doi:10.1108/JMP-03-2017-0115.

Davies, M., and S. Buisine. 2024. "Characterizing the Culture of Teal Organizations." *Organizational Cultures: An International Journal* 24 (1): 117–138. doi:10.18848/2327-8013/CGP/v24i01/117-138.

Deci, E. L., A. H. Olafsen, and R. M. Ryan. 2017. "Self-Determination Theory in Work Organizations: The State of a Science." *Annual Review of Organizational Psychology and Organizational Behavior* 4 (1): 19–43. doi:10.1146/annurev-orgpsych-032516-113108.

Deci, E. L., and R. M. Ryan. 2000. "The 'What' and 'Why' of Goal Pursuits: Human Needs and the Self-Determination of Behavior." *Psychological Inquiry* 11 (4): 227–268. doi:10.1207/S15327965PLI1104_01.

Diener, E. 1984. "Subjective Well-Being." *Psychological Bulletin* 95 (3): 542–575. doi:10.1037/0033-2909.95.3.542.

Dixon-Declève, S., P.A. Balland, F. Bria, C. Charveriat, K. Dunlop, E. Giovannini, D. Tataj, C. Hidalgo, A. Huang, D. Isaksson, F. Martins, M. Mir Roca, A. Morlet, A. Renda, and S. Schwaag Serger. 2022. *Industry 5.0: A Transformative Vision for Europe*. Brussels: European Commission.

Fourquet-Mahéo, S., H. Henri, D. Kaplan, and J.F. Marchandise. 2019. *Usine du futur, développement durable et numérique: les controverses de l'usine du futur*. Rapport d'étude ADEME & FING. Angers: Editions de l'ADEME.

Gagné, M., and E. L. Deci. 2005. "Self-Determination Theory and Work Motivation." *Journal of Organizational Behavior* 26 (4): 331–362. doi:10.1002/job.322.

Gagné, M., J. Forest, M. Vansteenkiste, L. Crevier-Braud, A. van den Broeck, A.K. Aspeli, J. Bellerose, C. Benabou, E. Chemolli, S.T. Güntert, H. Halvari, D.L. Indiyastuti, P.A. Johnson, M.H. Molstad, M. Naudin, A. Ndao, A.H. Olafsen, P. Roussel, Z. Wang, and C. Westbye. 2015. "The Multidimensional Work Motivation Scale: Validation Evidence in Seven Languages and Nine Countries." *European Journal of Work and Organizational Psychology* 24 (2): 178–196. doi:10.1080/1359432X.2013.877892.

Gagné, M., S.K. Parker, M.A. Griffin, P.D. Dunlop, C. Knight, F.E. Klonek, and X. Parent-Rocheleau. 2022. "Understanding and Shaping the Future of Work with Self-Determination Theory." *Nature Reviews Psychology* 1 (7): 378–392. doi:10.1038/s44159-022-00056-w.

Gat, A., Deudney, Ikenberry, G.J. Inglehart, R, and Welzel, C. 2009. "Which Way is History Marching? Debating the Authoritarian Revival." *Foreign Affairs* 88: 159–168.

Gillet, N., E. Fouquereau, J. Lequeurre, L. Bigot, and R. Mokounkolo. 2012. "Validation D'une Échelle De Frustration Des Besoins Psychologiques au Travail (EFBPT)—Validation of a Scale for Measuring Psychological Need Thwarting at Work (EFBPT)." *Psychologie du Travail Et Des Organisations* 18 (4): 328–344. doi:10.1016/S1420-2530(16)30074-7.

Godet, M., and F. Roubelat. 1996. "Creating the Future: The Use and Misuse of Scenarios." *Long Range Planning* 29 (2): 164–171. doi:10.1016/0024-6301(96)00004-0.

Görmüş, A. 2019. "Future of Work with the Industry 4.0." In *Proceedings of: International Congress on Social Sciences INCSOS 2019*, Vol. 1, No. 32, 317–323. Dordrecht, The Netherlands: Atlantis Press.

Graves, C. W. 1970. "Levels of Existence: An Open System Theory of Values." *Journal of Humanistic Psychology* 10 (2): 131–155. doi:10.1177/002216787001000205.

Inglehart, R. 2020. *Modernization and Postmodernization: Cultural, Economic, and Political Change in 43 Societies*. Princeton (NJ): Princeton University Press.

Inglehart, R., and W.E. Baker. 2000. "Modernization, Cultural Change, and the Persistence of Traditional Values." *American Sociological Review* 65 (1): 19–51. doi:10.1177/000312240006500103.

Inglehart, R., and C. Welzel. 2010. "What Do we Know about Modernization Today?" *Foreign Affairs* 88 (2): 33–48.

Johnson, M., J. M. Bradshaw, P. J. Feltovich, C. M. Jonker, M. B. Van Riemsdijk, and M. Sierhuis. 2014. "Coactive Design: Designing Support for Interdependence in Joint Activity." *Journal of Human-Robot Interaction* 3 (1): 43–69. doi:10.5898/JHRI.3.1.Johnson.

Johnson, M., M. Vignati, and D. Duran. 2018. "Understanding Human-Autonomy Teaming through Interdependence Analysis." In *Symp. Hum. Auton. Teaming* 1: 1–20.

Kaasinen, E., F. Schmalfuß, C. Özturk, S. Aromaa, M. Boubekeur, J. Heilala, P. Heikkilä, T. Kuula, M. Liinasuo, S. Mach, R. Mehta, E. Petäjä, and T. Walter. 2020. "Empowering and Engaging Industrial Workers with Operator 4.0 Solutions." *Computers & Industrial Engineering* 139: 105678. doi:10.1016/j.cie.2019.01.052.

Kadir, B.A., O. Broberg, and C. Souza da Conceição. 2019. "Current Research and Future Perspectives on Human Factors and Ergonomics in Industry 4.0." *Computers & Industrial Engineering* 137: 106004. doi:10.1016/j.cie.2019.106004.

Kern, M.L., L.E. Waters, A. Adler, and M.A. White. 2015. "A Multidimensional Approach to Measuring Well-Being in Students: Application of the PERMA Framework." *The Journal of Positive Psychology* 10 (3): 262–271. doi:10.1080/17439760.2014.936962.

Kotera, Y., G. Kaluzeviciute, G. Gulcan, K. McEwan, and K. Chamberlain. 2021. "Health Benefits of Ikigai: A Review of Literature.". In *Ikigai: Towards a Psychological Understanding of a Life Worth Living*, 1–13. Derby: Concurrent Disorders Society Publishing.

Kumano, M. 2006. "The Structure of Ikigai and Similar Concepts." *The Japanese Journal of Health Psychology* 19 (1): 56–66. doi:10.11560/jahp.19.1_56.

Lallemand, C., and G. Gronier. 2018. *Méthodes de design UX: 30 méthodes fondamentales pour concevoir des expériences optimales*. 2e éd. Paris: Eyrolles.

Lallemand, C., and V. Koenig. 2017. "How Could an Intranet be Like a Friend to Me? Why Standardized UX Scales Don't Always Fit." *Proceedings of the European Conference on Cognitive Ergonomics*, 9–16.

Laloux, F. 2014. *Reinventing Organizations: A Guide to Creating Organizations Inspired by the Next Stage in Human Consciousness*. 1st ed. Brussels: Nelson Parker.

Mahmoud, A.B., L. Fuxman, I. Mohr, W.D. Reisel, and N. Grigoriou. 2020. "We Aren't Your Reincarnation!' Workplace Motivation across X, Y and Z Generations." *International Journal of Manpower*. 42 (1): 193–209.

Markus, H., and S. Kitayama. 1991. "Culture and the Self: Implications for Cognition, Emotion, and Motivation." *Psychological Review* 98 (2): 224–253. doi:10.1037/0033-295X.98.2.224.

Mathews, G. 1996. "The Stuff of Dreams, Fading: Ikigai and 'The Japanese Self." *Ethos* 24 (4): 718–747. doi:10.1525/eth.1996.24.4.02a00060.

Mehra, P., and C. Nickerson. 2019. "Organizational Communication and Job Satisfaction: What Role Do Generational Differences Play?" *International Journal of Organizational Analysis* 27 (3): 524–547. doi:10.1108/IJOA-12-2017-1297.

Molino, M., C.G. Cortese, and C. Ghislieri. 2020. "The Promotion of Technology Acceptance and Work Engagement in Industry 4.0: From Personal Resources to Information and Training." *International Journal of Environmental Research and Public Health* 17 (7): 2438. doi:10.3390/ijerph17072438.

Nakanishi, N. 1999. "Ikigai' in Older Japanese People." *Age and Ageing* 28 (3): 323–324. doi:10.1093/ageing/28.3.323.

Neumann, W.P., S. Winkelhaus, E.H. Grosse, and C.H. Glock. 2021. "Industry 4.0 and the Human Factor – A Systems Framework and Analysis Methodology for Successful Development." *International Journal of Production Economics* 233: 107992. doi:10.1016/j.ijpe.2020.107992.

Oyserman, D., and S.W.S. Lee. 2008. "Does Culture Influence What and How we Think? Effects of Priming Individualism and Collectivism." *Psychological Bulletin* 134 (2): 311–342. doi:10.1037/0033-2909.134.2.311.

Passalacqua, M., G. Cabour, R. Pellerin, P. M. Léger, and P. Doyon-Poulin. 2024. "Human-Centered AI for Industry 5.0 (HUMAI5. 0): Design Framework and Case Studies." In *Human-Centered AI*, 260–274. London: Chapman and Hall/CRC.

Ratcliffe, J. S. 2006. "Challenges for Corporate Foresight: Towards Strategic Prospective through Scenario Thinking." *Foresight* 8 (1): 39–54. doi:10.1108/14636680610647138.

Rauch, E., C. Linder, and P. Dallasega. 2020. "Anthropocentric Perspective of Production before and within Industry 4.0." *Computers & Industrial Engineering* 139: 105644. doi:10.1016/j.cie.2019.01.018.

Robert, J.M, and E. Brangier. 2024. "Overview of Methods for Prospective Ergonomics." *Ergonomics:* 1–18. doi:10.1080/00140139.2024.2409939.

Rudolph, C.W., R.S. Rauvola, D.P. Costanza, and H. Zacher. 2021. "Generations and Generational Differences: Debunking Myths in Organizational Science and Practice and Paving New Paths Forward." *Journal of Business and Psychology* 36 (6): 945–967. doi:10.1007/s10869-020-09715-2.

Ryan, R.M, and E.L. Deci. 2001. "On Happiness and Human Potentials: A Review of Research on Hedonic and Eudaimonic Well-Being." *Annual Review of Psychology* 52 (1): 141–166. doi:10.1146/annurev.psych.52.1.141.

Ryan, R.M., V. Huta, and E.L. Deci. 2008. "Living Well: A Self-Determination Theory Perspective on Eudaimonia." *Journal of Happiness Studies* 9 (1): 139–170. doi:10.1007/s10902-006-9023-4.

Sartore, M., S. Buisine, I. Ocnarescu, and L.-R. Joly. 2023. "An Integrated Cognitive-Motivational Model of Ikigai (Purpose in Life) in the Workplace." *Europe's Journal of Psychology* 19 (4): 387–400. doi:10.5964/ejop.9943.

Sartore, M., I. Ocnarescu, LR. Joly, S. Buisine 2022. "Ikigai Robotics: How Could Robots Satisfy Social Needs in a Professional Context?" In *Proceedings of ICSR 2022 14th International Conference on Social Robotics*, LNAI 13818, edited by F. Cavallo., et al, 701–709.

Schaufeli, W.B., M. Salanova, V. González-Romá, and A.B. Bakker. 2002. "The Measurement of Engagement and Burnout: A Two Sample Confirmatory Factor Analytic Approach." *Journal of Happiness Studies* 3 (1): 71–92. [Mismatch] doi:10.1023/A:1015630930326.

Seligman, M. E. P. 2018. "PERMA and the Building Blocks of Well-Being." *The Journal of Positive Psychology* 13 (4): 333–335. doi:10.1080/17439760.2018.1437466.

Sone, T., N. Nakaya, K. Ohmori, T. Shimazu, M. Higashiguchi, M. Kakizaki, N. Kikuchi, S. Kuriyama, and I. Tsuji. 2008. "Sense of Life Worth Living (Ikigai) and Mortality in Japan: Ohsaki Study." *Psychosomatic Medicine* 70 (6): 709–715. doi:10.1097/PSY.0b013e31817e7e64.

Steger, M., B. J. Dik, and R. D. Duffy. 2012. "Measuring Meaningful Work: The Work as Meaning Inventory (WAMI)." *Journal of Career Assessment* 20 (3): 322–337. doi:10.1177/1069072711436160.

Szalma, J. L. 2014. "On the Application of Motivation Theory to Human Factors/Ergonomics: Motivational Design Principles for Human–Technology Interaction." *Human Factors* 56 (8): 1453–1471. doi:10.1177/0018720814553471.

Tanno, K., K. Sakata, M. Ohsawa, T. Onoda, K. Itai, Y. Yaegashi, and A. Tamakoshi. 2009. "Associations of Ikigai as a Positive Psychological Factor with All-Cause Mortality and Cause-Specific Mortality among Middle-Aged and Elderly Japanese People: Findings from the Japan Collaborative Cohort Study." *Journal of Psychosomatic Research* 67 (1): 67–75. doi:10.1016/j.jpsychores.2008.10.018.

Todorović, Z. 2022. "The Formation of a Multipolar World Order in International Relations in the XXI Century – Review of the Balkans." In Proceedings of FRESKA, Future, Research and Expectations in Science, Knowledge, and Aspirations, Banja Luka, 133–143. doi:10.7251/ZNUBL2201133T.

Van den Broeck, A., J.L. Howard, Y. Van Vaerenbergh, H. Leroy, and M. Gagné. 2021. "Beyond Intrinsic and Extrinsic Motivation: A Meta-Analysis on Self-Determination Theory's Multidimensional Conceptualization of Work Motivation." *Organizational Psychology Review* 11 (3): 240–273. doi:10.1177/20413866211006173.

Van den Broeck, A., M. Vansteenkiste, H. De Witte, B. Soenens, and W. Lens. 2010. "Capturing Autonomy, Competence, and Relatedness at Work: Construction and Initial Validation of the Work-Related Basic Need Satisfaction Scale." *Journal of Occupational and Organizational Psychology* 83 (4): 981–1002. doi:10.1348/096317909X481382.

Welzel, C. 2014. "Evolution, Empowerment, and Emancipation: How Societies Climb the Freedom Ladder." *World Development* 64: 33–51. doi:10.1016/j.worlddev.2014.05.016.

Wilber, K. 2001. *A Theory of Everything: An Integral Vision for Business, Politics, Science and Spirituality*. Boulder (CO): Shambhala Publications.

Wioland, L., L. Debay, and J. J. Atain-Kouadio. 2019. "Processus d'acceptabilité et d'acceptation des exosquelettes: Évaluation par questionnaire." *Références en Santé au Travail* 160: 49–76.