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The impact of the temperament model on the behavior of an autonomous driver

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Abstract: Because it is generally believed that the personality and temperament of a human driver influence his/her behavior on the road, the article presents a computational model of the temperament of an autonomous agent - a driver. First, a short review of the four ideas of Galen's temperament in psychology is presented. Temperament traits are grouped into four other sets, one of which is chosen for implementation in the project of integration of the temperament model with the target autonomous agent. On the basis of this selection, it is proposed to modify, by introducing additional useful mechanisms of temperament, the existing model (ISD) of an autonomous robot and/or driver. In addition, other ways of extending the ISD model are indicated, as well as possible applications of the proposed system. The developed model may also be interesting for other research purposes in which the description of the human personality is important.

Keywords: Learning, adaptation, autonomous vehicles, artificial intelligence, cognitive aspects.

1. INTRODUCTION

There are over 800 million cars that are used to transport people, and for many years we have had the opportunity to observe developments in this particular area (Thrun, 2010). In this way, the level of computerization of vehicles has been increased, as well as their autonomy. Fully autonomous cars were announced for 2021.

The driver and his/her personality are the main factor affecting the overall safety of the driver himself, car and traffic environment. A safe driver is characterized by a well-balanced and strong nervous system that makes his reactions timely and correct (Šucha and Seitl, 2011). On the other hand, impulsive, irresponsible, reckless, emotionally oversensitive, and sometimes hesitant or restless driver is seen as a problem on the road. The features described above belong to the temperament of the driver. We can clearly see how these features can affect the driving process itself, which consists of many decisions taken at a low level (when to switch gears, when to overtake, how much to press the brake pedal) and at a high level (which path to choose, how early we must start to have a safe time limit, and even what kind of music we will listen to while driving, because it has some effect on the driver's performance). Therefore, it can be stated that the behavior of the driver (in the context of his reaction) depends mainly on his temperament (van der Zwaag et al., 2012).

A more curious driver (what results from his temperament) feels the need to use a mobile phone while driving. This is a serious problem because about one in four car accidents are caused by the use of mobile phones in the USA (Kratsas, 2014). However, even an autonomous driver can participate in an accident, as was the case in the last famous event (Levin and Wong, 2018).

As shown, the temperament of the driver is one of many factors affecting the overall safety of car transport. Thus, the modeling of the driver's temperament can lead to the recognition of features that can distinguish a safe driver from a reckless driver. First, however, you need to define the temperament itself.

Assuming there is some influence of the driver's temperament on his behavior on the road and to analyze this problem, both in terms of analysis and the synthesis of the automatic driver, in this article we present the concept of a new model of human temperament. Such a model may also be interesting for other research purposes in which the description of the human personality is important. The introduced temperament model is based on the concept of intelligent decision making system (ISD) developed for robotic applications, and presented in the series of our works (Kowalczuk and Czubenko, 2010a,b, 2011, 2013, 2014; Czubenko et al., 2015; Kowalczuk and Czubenko, 2017; Czubenko, 2017). This article presents preliminary results on the driver's temperament model, and the necessary experimental studies and practical results should take place in the near future.

2. STATE OF THE ART

There are many different approaches to personality aspects in scientific psychology. The applied definitions of personality may be different in the context of perspectives of cognitive and biological, psychodynamics, and traits (Corr and Matthews, 2009). However, creating a model taking into account all these different approaches is an extremely difficult task (Kowalczuk and Czubenko, 2010a).

There are many personality models used in modern psychology (such as Big5 or MBTA). However, the personality does not have one single best model suitable for the general

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purpose. In this paper, temperament – an old but fairly unambiguous concept – is chosen for system considerations. With this model, we assume that human temperament can be divided into four types, also characterized by the so-called *body humor*, as shown in table 1. This theory dates back to 400 BC, when Hippocrates formulated his four types of 'fluids'. His research was continued by Galen, who describes a theory of four temperaments (Merenda, 1987). To define four temperaments for an autonomous driver, it is worth using what has been described in psychology.

Table 1. Temperaments and liquids according to Hippocrates and Galen.

Temperament type	**Body humor**	**Description**
Choleric	yellow bile	irascible
Melancholic	black bile	sad
Phlegmatic	phlegm	apathetic
Sanguine	blood	optimistic

In his work, Merenda (1987) analyzes a whole chain of historical ways of assessing personality from the Galen model to the ideas of the 20th century. Among numerous models, in particular, he considers:

- Hippocrates-Galen-Kant model
- Eynsyck's model (modfied by Wundt)
- Activity Vector Analysis.

In summary, Marenda saw certain parallels between the four types of Galen's temperament and the contemporary four-factor personality theory. However, later Lester (1990) disagreed with this comparison, showing simply that later personality theories are more complex than the simple Galen model. He analyzed the following models with the aim of assigning them to the four temperaments:

- Allport's twofold dichotomies
- 3D behavior of Heymans & Wiersma
- Pavlov's types of nervous systems
- 4 Adler's types of people by Ansbacher & Ansbacher
- Stagner 2D behavior matched by Diamond
- 16 Jung & Myers' personalities according to Keirsey & Bates.

It is noteworthy that these strong four types of Galen include only two dimensions, in contrast to modern four- and five-dimensional personality models.

Both works provide a rich set of attributes (adjectives) describing each type of temperament. This allows us to collect, organize and express them in the form of table 2, bearing in mind the features that may be interesting from the point of view of autonomous driving. We distinguish the following main groups:

(1) emotional traits
(2) personality traits
(3) social traits
(4) sensitivity traits.

The emotional traits refer to the depth of feeling, especially in the emotion context, which are reflected in the behavior of human. The DEW and SUA acronyms include fixed sets of adjectives in columns. DEW, coming from *Deep-Emotional-Withdrawal*, describes the features associated with introvert personality type. Whereas, SUA, standing for the opposite *Shallow-Unemotional-Approach*, which tend to describe extrovert individuals.

The next characteristic group includes personality traits that specifically refer to the 16 possible personalities defined by Jung and Myers, and have therefore been classified as a separate group. Myers' dichotomy of perception /judgment has been combined with Jung's original dichotomy of thinking/feeling and marked as a meta-cognitive function of attention (Kowalczuk and Czubenko, 2011). The meta-cognitive function of attention focuses human resources on a certain cognitive process. So, for example, someone can better perceive objects in the environment while the other has a better sense of judgment. The effects of such a function, in the context of the desired modifications of the xEmotion model, are further discussed in section 3.

Social traits clearly show how a person with a given personality relates to interacting with others. Appropriately selected adjectives describe the behavior of such a person in a social context.

The sensitivity trait describes how stable the emotional state of a person is. CSU is an acronym describing the set of *Calm-Secondary-Unchangeable*, while EPC is an abbreviation for *Excited-Primary-Changeable*. In our simplified approach, melancholic and choleric temperaments have been selected as extreme bipolar (dichotomic) instances of sensitivity. On the other hand, the sanguine and phlegmatic temperaments are somewhere in the middle, but due to the high similarity (common values) they can be approximately equivalent to the temperaments of cholerics and melancholics.

Undoubtedly, one might think about how to include the complete model of temperament into an autonomous driver based on the characteristics presented in tab. 2. In our first approach, to build an artificial driver model, we suggest to consider only selected categories of description of the basic four types of temperament, namely, features (traits) related to one category highlighted in this table with bold text in each separate group of attributes.

3. TEMPERAMENT MODEL

To study the influence of the temperament model on the behavior of an autonomous driver, we must choose the appropriate models for both temperament and the artificial driver. The basis of this study will be an Intelligent System of Decision-making (ISD) that uses the concepts of artificial needs, emotions, mood, and cognitive processes (Kowalczuk and Czubenko, 2011, 2013). In addition, as an driver model, an ISD-based xDriver will be used, described in (Czubenko et al., 2015), which contains all the necessary concepts of human perception and cognition.

Taking into account the temperament in our target ISD system can possibly be carried out in several points of the system affecting the basic ISD mechanisms, such as needs and emotions, and cognitive processes of the agent, including attention memory and long-term memory, which are described in detail in (Kowalczuk and Czubenko, 2011, 2016, 2014, 2017; Czubenko, 2017).

Considering the agent's needs, temperament can:

Table 2. Features of four Galen temperaments (from the viewpoint of an autonomous driver).

Characteristic group	**Category**	**Sanguine**	**Melancholic**	**Choleric**	**Phlegmatic**
Emotional traits (types DEW,SUA/ introvert,extrovert)	emotional impact	unemotional	emotional	emotional	unemotional
	impact depth	shallow	deep	deep	shallow
	nervous balance	**balanced-alternating**	**inhibitory**	**excitatory**	**balanced-steady**
	attraction level	approach	withdrawal	withdrawal	approach
Personality traits	type of sensing	sensing	sensing	intuiting	intuiting
	meta-cognitive	**perceiving**	**judging**	**feeling**	**realistic thinking**
Social traits	activity level	high activity	lowest activity	high activity	low activity
	sociability level (social interest)	**high**	**lowest**	**low**	**low**
	interpersonal touch	optimistic/hopeful	sad/depressed	irascible	apathetic
	social susceptibility	sociability	tractability	assertiveness	tranquility
	pleasant aspect	pleasant	unpleasant	unpleasant	pleasant
	social activity	sympathetic	parasympathetic	sympathetic	parasympathetic
	social situation	favorable	unfavorable	unfavorable	favorable
	social values	easy going	anxious	active	high-principled
		sociable	worried	histrionic	reasonable
		carefree	unhappy	hot-headed	controlled
		playful	serious	egocentric	persistent
		hopeful	suspicious	exhibitionist	steadfast
		contented	thoughtful	quickly-roused	calm
Sensitivity traits (types CSU,EPC/ melancholic,choleric)	inertia type	changeable	unchangeable	changeable	unchangeable
	state type	excited	calm	excited	calm
	vulnerability	broad	narrow	broad	narrow
	ambient impact	**primary**	**secondary**	**primary**	**secondary**
	internal state	excitement	depression	excitement	depression

- change the kernel and support of fuzzy membership functions (which determine the agent's needs system)
- concentrate or dilute fuzzy sets
- modify the (significance) weighting parameters of various system functions.

In addition, taking into account the second motivation system in ISD, temperament should affect emotions by changing:

- parameters describing (sensory) pre-emotions
- factor (δ) of calming down the classical emotion (moving towards the center of the emotion circle)
- mental health parameter (Υ).

What's more, temperament should influence the recording of discoveries related to a specific triggered emotion or equale (aspect of long-term memory). It should also have an impact on the level of attention and subconscious reactions of the agent.

Of the above-mentioned methods, only a few have been studied in detail, namely those that can be easily interpreted in the temperament characteristics represented by the categories (one in each group) detailed in bold in the table 2. This means that the following methods have been selected:

(1) nervous balance (emotional trait) – modeled by modifying the intensity of the calming effect
(2) social activity/trait (high or low) – controlled by changing the fuzzy membership function that represents sociability (mental belonging to the populance)
(3) meta-cognitive function (personality trait) – shaped by appropriate invoking (boosting) of the attention function
(4) ambient impact (primary or secondary; sensitivity trait) – modeled by scaling the impact of upcoming observations.

The nerve balance values listed in the table can be sorted in ascending order in terms of the ability to stay calm:

(1) melancholic – inhibitory
(2) phlegmatic – balanced-steady
(3) sanguine – balanced-alternating
(4) choleric – excitatory (excitant, affective).

An agent with a melancholy disposition requires a strong stimulation from the environment, so that such external observation will affect him, otherwise he remains calm. On the other hand, a choleric agent can be easily aroused and it is not easy to calm him down. Thus, melancholy causes the attraction to the center of the wheel of emotions much faster than the choleric type. This effect can be achieved by properly tuning the calming down parameter $\delta \in (0,1)$ – the intensity that scales the shift towards the center of the emotion circle. The choleric agent will be characterized by $\delta \approx 0$, while the melancholy one will have $\delta \approx 1$.

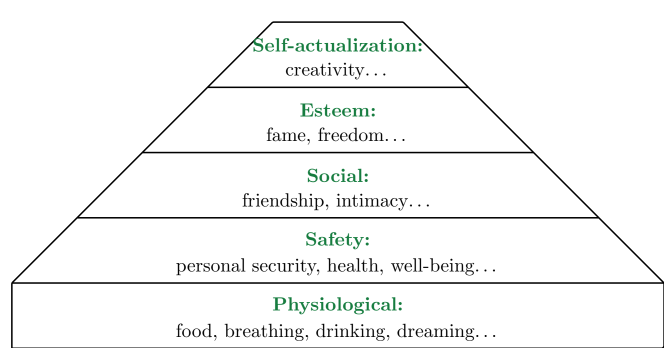

Fig. 1. Social needs in Maslow's hierarchy of needs.

As mentioned above, modeling the social interest (characteristics) in the context of temperaments can be achieved by appropriately modifying the membership function in the agent's needs system. Thus, the level of sociability (social trait) can shift satisfaction, alarm and pre-alarm functions along the obscissa (thereby modifying the kernel and support of the respective fuzzy sets), and can affect the concentration or dilution of these fuzzy sets.

These operations should affect only the needs of the social level in the Maslow pyramid shown in Fig. 1. As a rule, agents with a temperament characterized by a higher level of social interest quickly become dissatisfied if they do not engage in social activities. This means that in the case of a highly social type all fuzzy sets are shifted to the left. This reduces the kernel and support of the function of membership to the state of satisfaction and increases them in the case of pre-alarm and alarm functions.

The fuzzy functions of membership to a social need are defined as follows:

$$\mu_s(\eta) = f_Z(\eta) = \begin{cases} 1, & \eta \le \upsilon_s \\ 1-2(\frac{\eta-\upsilon_s}{\upsilon_p-\upsilon_s})^2, & \upsilon_s < \eta \le (\upsilon_s+\upsilon_p)/2 \\ 2(\frac{\eta-\upsilon_s}{\upsilon_p-\upsilon_s})^2, & (\upsilon_s+\upsilon_p)/2 < \eta \le \upsilon_p \\ 0, & \eta > \upsilon_p \end{cases} \tag{1}$$

$$\mu_a(\eta) = f_S(\eta) = \begin{cases} 0, & \eta \le \upsilon_p \\ 2(\frac{\eta-\upsilon_a}{\upsilon_a-\upsilon_p})^2, & \upsilon_p < \eta \le (\upsilon_a+\upsilon_p)/2 \\ 1-2(\frac{\eta-\upsilon_a}{\upsilon_a-\upsilon_p})^2, & (\upsilon_a+\upsilon_p)/2 < \eta \le \upsilon_a \\ 1, & \eta > \upsilon_a \end{cases} \tag{2}$$

$$\mu_p(\eta) = f_\Pi(\eta) = \begin{cases} 1-f_Z(\eta), & \eta \le \upsilon_p \\ 1-f_S(\eta), & \eta > \upsilon_p \end{cases} \tag{3}$$

where η is the level of dissatisfaction (of this social need), υ_a, υ_s and υ_p are are parameters, and μ_s, μ_p and μ_p are the membership functions for the state of satisfaction, prealarm, and alarm, respectively, of this need (Czubenko, 2017). An example fuzzy description template for the needs modeled in the ISD system is shown in Fig. 2.

Therefore, the social interest can be represented by a fixed value $c \in \mathbb{R}$, and the resulting modified – shifted – fuzzy membership functions can be given by $\hat{\mu}_j(\eta) = \mu_j(\eta + c)$, $j \in \{s, p, a\}$ where $\mu_j(\eta)$ is the primary function of membership to the social need of an agent with 'medium' social involvement. Note that if you move the sets to the right ($c > 0$), the satisfaction function increases its support, while the alarm function support decreases. In order to further enhance this effect, it is suggested to use an additional concentration/dilution operation on sets with a reduced/increased support (after the shifting). In the case of social needs, combining these two operations on the fuzzy sets after moving $\mu_j(eta)$ leads to the following equation:

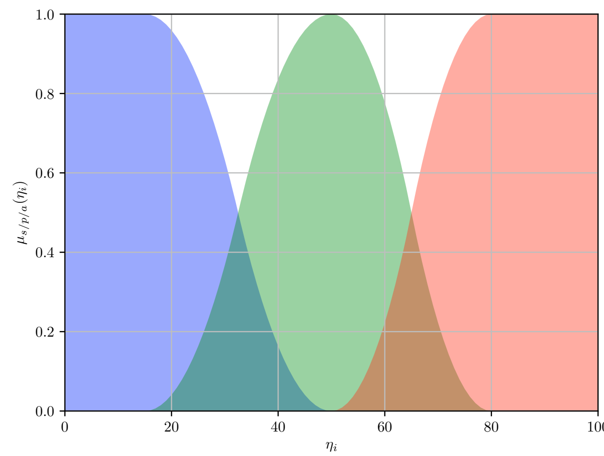

Fig. 2. The concept of a fuzzy description of the need by means of three membership functions and corresponding language variables representing satisfaction (s), pre-alarm (p) and alarm (a).

$$\bar{\mu}_j(\eta) = \begin{cases} \hat{\mu}_j(\eta)^2, & \text{if } c(\frac{d\mu_j(\eta)}{d\eta}) < 0 \\ \hat{\mu}_j(\eta), & \text{if } c(\frac{d\mu_j(\eta)}{d\eta}) = 0 \\ \hat{\mu}_j(\eta)^{\frac{1}{2}}, & \text{if } c(\frac{d\mu_j(\eta)}{d\eta}) > 0 \end{cases} \tag{4}$$

where $\bar{\mu}_j(\eta), j \in \{s, p, a\}$ is the final fuzzy function of membership to a social need after both operations (shifting and concentrating or diluting).

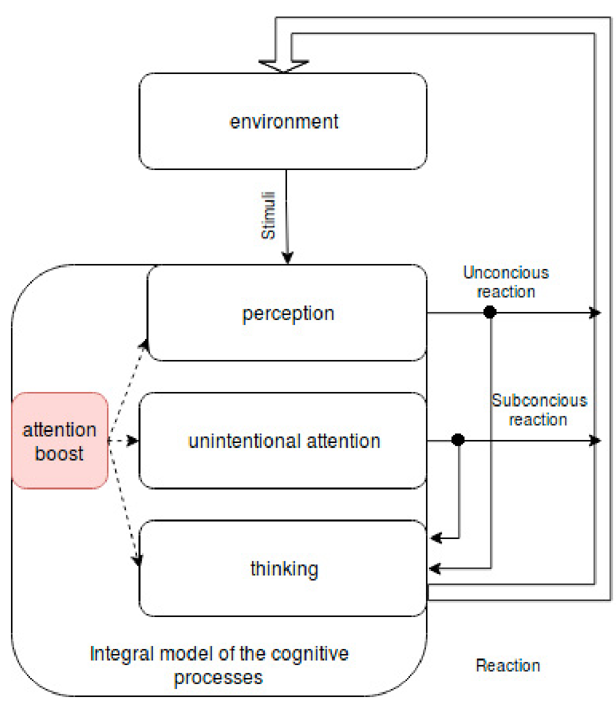

Fig. 3. Modified model of cognitive processes with control (boost) of attention.

The meta-cognitive function controls attention by simply boosting attention. Figure 3 shows the simplified model of cognitive processes used (Kowalczuk and Czubenko, 2010a).

It is proposed to introduce a form of controlling the allocation of perceptive resources to the perception, unintentional attention and thinking functions. Such a solution would effectively enable us to distinguish meta-cognitive functions related to realistic thinking/judging, with more resources allocated to the center of thinking, and meta-cognitive functions of feeling/perceiving based to a greater extent on the subconscious.

The sensitivity trait is represented by the primary-secondary dichotomy of the environmental impact. It determines how the stimuli affect the individual internal state (the effect of the external stimulus may be primary or secondary to the current emotional state). One of the effective ways to account for the extent to which impact observations will affect the observer would be to shift the center of the sub-emotions κ^c, which is basically the sum of the observation of emotional effects (external stimuli) on the wheel of emotions. You can do it in the following way:

$$\hat{r}_{\kappa^c} = min(r_{max}, k r_{\kappa^c}) \tag{5}$$

Using the polar coordinate system for the sub-emotion center (point on the emotional wheel) $\kappa^c = r_{\kappa^c} e^{j\omega_{\kappa^c}} = (r_{\kappa^c}; \omega_{\kappa^c})$ would require modifying the radius r_{κ^c} of the sub-emotion center, according to equation (5), where $\hat{r}_{\kappa^c}$ is the new sub-emotion radius, $r_{max} = 100$ is the maximum allowed sub-emotion radius and k is one of two values – 0.5 in the case of a secondary ambient impact type and 2 in the primary case (Czubenko, 2017).

Controlling each of these parameters gives you enough freedom to model all considered types of temperament.

4. CONCLUSIONS

At the end, it is worth recalling that due to the multiplicity of points of view on the human personality in modern psychology, it is difficult to choose the best for a particular application. The four temperaments of Gallen present a simple view of classifying the human personality, but they are very stable and have a long history.

A method was proposed to include four of Gallen's temperaments in the existing xDriver system. Using such a system can improve the human experience of interacting with an autonomous driver. Considering the proposed parameters controlling the behavior of the driver's agent, it is also possible to set the driver for a mixture of temperaments. This is also reflected in the human archetype of the driver, as some people may not be easily classified into one of the classic four categories.

An ISD-based temperament model can also be used to determine the temperament of the human driver, based on his behavior on the road. The system proposed in this report is not yet sufficient for this task. In addition, further refinement of the methods proposed for temperament modeling may be required.

REFERENCES

Corr, P. and Matthews, G. (2009). *The Cambridge Handbook of Personality Psychology*. Cambridge University Press. doi:10.1017/CBO9780511596544.002.

Czubenko, M. (2017). *An anthropoid model of an intelligent decision system for autonomous units (in Polish: Antropoidalny model inteligentnego systemu decyzyjnego dla jednostek autonomicznych)*. Ph.D. thesis, Gdańsk University of Technology, Faculty of Electronics, Telecommunications and Informatics, Gdańsk.

Czubenko, M., Kowalczuk, Z., and Ordys, A. (2015). Autonomous driver based on intelligent system of decision-making. *Cognitive Computation*, 7(5), 569–581.

Kowalczuk, Z. and Czubenko, M. (2017). Emotions embodied in the SVC of an autonomous driver system. *IFAC-PapersOnLine*, 50(1), 3744–3749.

Kowalczuk, Z. and Czubenko, M. (2010a). Interactive cognitive-behavioural decision making system. In *Artifical Intelligence and Soft Computing*, volume 6114 (II) of *LNAI*, 516–523. Springer Verlag, Berlin.

Kowalczuk, Z. and Czubenko, M. (2010b). Model of human psychology for controlling autonomous robots. In *15th IEEE Intern. Conference on Methods & Models in Automation & Robotics*, 31–36.

Kowalczuk, Z. and Czubenko, M. (2011). Intelligent decision-making system for autonomous robots. *Intern. Journal of Applied Mathematics and Computer Science*, 21(4), 621–635.

Kowalczuk, Z. and Czubenko, M. (2013). xEmotion – computational model of emotions dedicated for an intelligent system of decision-making (in polish). *Pomiary, Automatyka, Robotyka*, 2(17), 60–65.

Kowalczuk, Z. and Czubenko, M. (2014). Cognitive memory for intelligent systems of decision-making, based on human psychology. In *Intelligent Systems in Technical and Medical Diagnostics*, volume 230 of *AISC*, 379–389. Springer, Berlin – Heidelberg.

Kowalczuk, Z. and Czubenko, M. (2016). Computational approaches to modeling artificial emotion – an overview of the proposed solutions. *Frontiers in Robotics and AI*, 3(21), 1–12.

Kratsas, G. (2014). Cellphone use causes over 1 in 4 car accidents. URL `https://eu.usatoday.com/story/money/cars/2014/03/28/cellphone-use-1-in-4-car-crashes/7018505/`.

Lester, D. (1990). Galen's four temperaments and four-factor theories of personality: A comment on "toward a four-factor theory of temperament and/or personality". *Journal of Personality Assessment*.

Levin, S. and Wong, J.C. (2018). Self-driving uber kills arizona woman in first fatal crash involving pedestrian. URL `https://www.theguardian.com/technology/2018/mar/19/uber-self-driving-car-kills-woman-arizona-`.

Merenda, P.F. (1987). Toward a four-factor theory of temperament and/or personality. *Journal of Personality Assessment*, 51(3), 367–374.

Šucha, M. and Seitl, M. (2011). The role of personality qualities in driving. *Transactions on Transport Sciences*, 4(4), 225–232.

Thrun, S. (2010). Toward robotic cars. *Communications of the ACM*, 53(4), 99.

van der Zwaag, M.D., Dijksterhuis, C., de Waard, D., Mulder, B.L., Westerink, J.H., and Brookhuis, K.A. (2012). The influence of music on mood and performance while driving. *Ergonomics*, 55(1), 12–22.