ERGONOMICS
2018, VOL. 61, NO. 12, 1613–1618
https://doi.org/10.1080/00140139.2018.1503727

Taylor & Francis
Taylor & Francis Group

ARTICLE

Check for updates

Does size matter? Spacious car cockpits may increase the probability of parking violations

Felix C. Meier[a], Markus Schöbel[b] and Markus A. Feufel[a,c]

[a]Technische Universität Berlin, Department of Psychology and Ergonomics, Division of Ergonomics, Berlin, Germany; [b]Universität Basel, Department of Psychology, Center for Economic Psychology, Basel, Switzerland; [c]Harding Center for Risk Literacy, Berlin, Germany

ABSTRACT
Cockpit design is a core area of human factors and ergonomics (HF/E). Ideally, good design compensates for human capacity limitations by distributing task requirements over human and interface to improve safety and performance. Recent empirical findings suggest that the mere spatial layout of car cockpits may influence driver behaviour, expanding current views on HF/E in cockpit design. To assess the reliability of findings showing that an expansive driver seat space predicts parking violations, we replicated an original field study in a geographically and socio-culturally different location and included an additional covariate. After controlling for car length, brand status, and car price, driver seat space remained a positive predictor of illegal parking. This suggests that the spatial design of vehicle cockpits may indeed have an influence on driver behaviour and may therefore be a relevant dimension to be included in research and applications of HF/E in cockpit design.

Practitioner summary: In car cockpit design, ergonomists typically focus on optimising human–machine interfaces to improve traffic safety. We replicate evidence showing that increasing physical space surrounding the driver relates to an increased probability of parking violations. This suggests that spatial design should be added to the ergonomist's toolbox for reducing traffic violations.

Abbreviation: HF/E: human factors and ergonomics.

ARTICLE HISTORY
Received 19 April 2018
Accepted 28 June 2018

KEYWORDS
Embodiment; expansive body postures; traffic safety; cockpit design; parking violations

1. Introduction

One of the success stories of human factors and ergonomics (HF/E) relates to cockpit design and its power to improve traffic behaviour and safety. Most of the accumulated evidence on HF/E in automobiles focuses on the design of control interfaces to support safe traffic behaviour or the biomechanical requirements for supporting an adequate field of view or the comfortable entry and exit from vehicles (Peters and Peters 2002; Bhise 2016). Little attention has so far been devoted to how the physical layout of car cockpits may shape traffic behaviour. Recent studies have shown that the spatial volume of car cockpits is linked to the probability of parking violations (see Study 4 in Yap et al. 2013). This finding is based on the idea that body postures that are more expansive (ie the body takes up more rather than less space) and/or more open (ie the position of limbs is open rather than closed) tend to enhance the psychological state of power (Carney, Cuddy, and Yap 2010), which in turn increase the probability of dishonest behaviour or rule violations (Carney, Cuddy, and Yap 2010). Yap et al. (2013) tested this effect in a real-world setting, showing that, in New York City, cars with a more expansive driver seat space were more likely to be illegally parked than cars with a more constrictive driver seat space.

Although effects of the role of the body in cognition (embodiment) have already been linked to HF/E on a theoretical level (Bagnara and Pozzi 2015), there is currently a lack of empirical evidence. With the present study, we follow up on the original field research by Yap et al. (2013) and provide additional empirical evidence by testing the reproducibility of the phenomenon in a different setting and discuss implications for HF/E and cockpit design. Before presenting our study, we elaborate the original study and its conceptual underpinnings.

CONTACT Felix C. Meier felix.meier@tu-berlin.de Technische Universität Berlin, Department of Psychology and Ergonomics, Division of Ergonomics, Marchstr. 23, MAR 3-2, 10587 Berlin, Germany

Supplemental data for this article can be accessed here.

1.1. Conceptual underpinnings

The field of embodied cognition contends that cognitive processes (eg those related to perception, working memory and decision making) cannot be understood as the mere processing of information in an isolated cerebral system. 'Instead, grounded cognition proposes that modal simulations, bodily states and situated action underlie cognition'. (Barsalou 2008, 617). In other words, an account of cognitive activity should be essentially grounded in people's physical and bodily environment.

One implementation of this idea relates to evidence suggesting that expansive body postures can induce a subjective feeling of power, leading to more risk taking and illegal behaviour (Hall, Coats, and LeBeau 2005; Carney, Cuddy, and Yap 2010), which Reason (1990) and Norman (2013) refer to as violations in their error taxonomies. Carney et al. (2010) demonstrated that body postures can trigger psychological as well as physiological changes in the laboratory. In their study, when they asked their participants to adopt a constrictive body posture, they measured increased cortisol levels indicating physiological stress. In contrast, expansive body postures tended to increase participants' testosterone levels, which are linked to increased risk tolerance and dominant behaviour. Accordingly, expansive postures led to riskier choices in a gambling task and an increased sense of power following the manipulation of body posture.

Given that this field of research is still young, there is a heated debate over the existence of body posture effects in the literature. One criticism relates to the robustness of the findings. In a replication of Carney et al.'s original study, Ranehill et al. (2015) confirmed the effect of expansive postures on subjective feelings of power, but could not replicate the effect of posture on risk tolerance, testosterone levels, or cortisol levels. Carney, Cuddy, and Yap (2015), in turn, summarized 33 published laboratory experiments demonstrating effects of body postures on a wide range of psychological and behavioural variables. Another criticism relates to methodological concerns of these 33 experiments, such as higher publication rates of significant findings versus null results (Simmons and Simonsohn 2017; for a recent rebuttal of this argument see Cuddy, Schultz, and Fosse 2018) or that 'These discrepant findings may, in part, be a function of differences in how data were analyzed'. (Credé and Phillips 2017, 493). In particular, Credé and Phillips used Carney et al.'s (2010) original data to demonstrate that the effects depended on the choice of dependent measures and control variables, and on the method that was used to select participants and detect outliers in the data.

With these methodological concerns in mind, the study presented in this article aims at testing the robustness of the effects of driver seat space on parking violations. Although the explanatory evidence obtained in former studies is neither clear cut nor very strong, we hypothesize that more physical space surrounding car drivers increases the probability of parking violations. Apart from contributing evidence on the effect of body postures on behaviour, we are primarily interested in the robustness of the link between the physical design of car cockpits and its behavioural consequences in a real-world setting. Therefore, we replicated and extended the methodology of Yap et al.'s (2013) field study (study 4 in their article), which investigates the relationship between the physical dimension of more or less constrictive driver seat spaces and parking violations. We outline the original study and our modifications next.

1.2. Original studies

Yap et al. (2013) conducted an experimental simulation (Study 3) and an observational field study (Study 4) that both investigated the influence of driver seat space on traffic violations. In a first driving simulator study (Study 3), participants in an expansive seat configuration violated rules more frequently than drivers in a constrictive seat space. Furthermore, sense of power mediated the association between body posture and violations. In Study 4, the authors investigated the effect of body postures on traffic violations using an observational field design. This study is one of the few attempts to test the effect of body posture on behaviour in a real-world setting. More specifically, Yap et al. identified double-parked cars and adjacent cars that parked legally in the area between the 116th and 102nd street in New York City. Then, they calculated driver seat spaces for both types of cars based on measures obtained from car manufacturers (for the exact procedure see Figure 1). In the last step, they performed logistic regressions to predict parking violations (yes–no) by driver seat space, controlling for car length and 'status' of car brands (because previous studies had linked social status to unethical behaviours/violations; Gino and Pierce 2009; Piff et al. 2012). In the first analysis with car status as covariate (*ns*), larger driver seat spaces related to an increased probability of double-parking compared to more constrictive driver seat spaces ($OR = 1.02$, $p < .001$). Given that finding sufficient legal parking space becomes

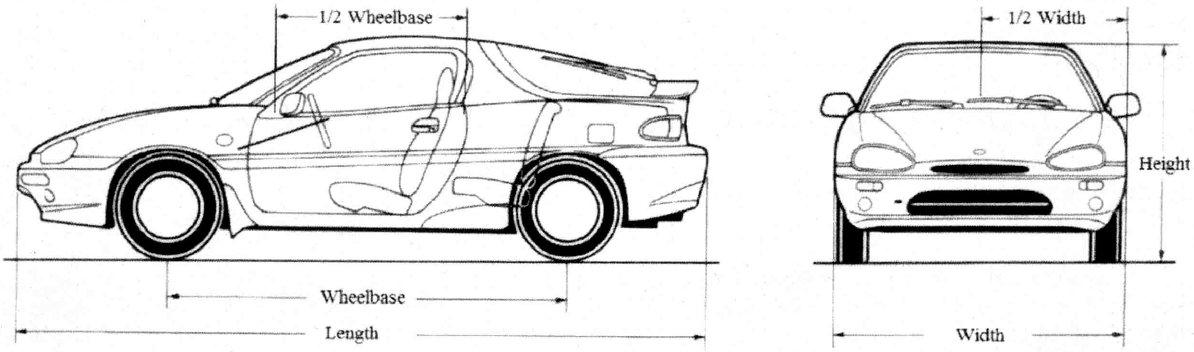

Figure 1. Schematic showing the measures used to compute driver seat space (½Wheelbase, Height, ½Width). Also, the control variable Length is shown. Adapted from Yap et al. (2013).

increasingly difficult for longer cars and car length is strongly correlated with driver seat size (Figure 1), car length was also included in the regression analysis. When controlling for both car status (*ns*) and car length (the authors do not provide information on its *p*-value), the effect of driver seat space on double parking was not statistically significant (OR =1.02, $p = .087$).

Despite converging evidence from simulation and field studies concerning the effect of driver seat space on parking violations, the external validity of Yap's et al. (2013) field study is limited in several ways. First, data collection took place in New York City in an area that is densely populated with well-developed public transport. Thus, it can be assumed that (a) only a specific segment of the general population is using and parking cars in this area and (b) challenges related to finding a parking spot might differ from less densely populated urban settings. Thus, parking behaviour in the studied area cannot be generalized to urban parking behaviour in general. Second, the authors focused exclusively on *double parking* as dependent variable, that is, cars parked in parallel to cars parked legally at the curb. No other parking violations were considered, and all violations were identified by the researchers without consulting with professional parking officers. Finally, the authors did not control for the price of the illegally parked cars as a potentially important covariate. Car price is known to be an indicator of the economic background of the driver (Gino and Pierce 2009; Piff et al. 2012). Thus, parking fines may matter less to drivers of more expensive cars and occur more often in a wealthy population, independent of the effect of driver seat space.

1.3. The present study

In the present study, we replicated the original field study by Yap et al. (2013) to test the robustness of the effect and address limitations of its research design. To do so, we ran the study in a different cultural and urban setting. Compared to New York City with about 10,430 inhabitants per square kilometre (Census Data 2011), our study took place in a much less densely populated, rural city in Southwestern Germany with about 749 inhabitants per square kilometre, where the need for violations is likely decreased thanks to more parking opportunities (Statistisches Bundesamt 2018). Also, we had parking inspectors identify any type of parking violation as dependent variable rather than focusing on the special case of double-parking alone. We also included car price as additional covariate.

2. Methods

Data collection took place in Offenburg, a midsize rural city in Germany with 55,000 inhabitants. A researcher accompanied parking inspectors in various districts of the city to gather information on cars that were parked illegally and cars that were parked correctly. Whenever an inspector identified a parking violation, the experimenter recorded its brand and model and collected the same information of a correctly parked car right beside it. If there was no correctly parked car within 10 m, the case was excluded. If there was more than one correctly parked car, the experimenter recorded the car whose steering wheel was next to the illegally parked car. Data collection was completed within two weeks.

Overall, 345 parking violations could be identified. Eighty-four cases had to be eliminated from the raw data set because no legally parked equivalent could be located within a perimeter of 10 m (37 cases) or information about the car model could not be obtained from the manufacturer (35 cases). Also, trucks and transporters were excluded, because there are different subtypes of the same vehicle models with varying wheelbases, heights and lengths, which could not be readily identified (12 cases). Overall, 261 illegally parked cars could be matched to 261 cars without parking violations (76% of the originally identified cars with parking violations) and were included in the final analysis.

To compute the available driver seat space behind the steering wheel, we used the formula $\frac{1}{4} \times$wheelbase $\times$ height $\times$ width (Figure 1), adapted from Yap et al. (2013). These measures, including car length and car price, were gathered from the car manufacturers' websites.

Car brand status was assessed using a survey methodology. The survey consisted of 28 items, one for each car brand. We asked 26 participants (Swiss and German university students) to rate brand status on a Likert scale ranging from 1 (the car brand has no prestige at all) to 7 (the car brand has very high prestige). Given the different dimensions of the data, all variables were standardized to *Z*-scores before data analysis.

3. Results

The means, standard deviations, and correlations among all study variables are shown in Table 1. To test the effect of driver seat space, car length, car price, and brand status on parking violations versus correct parking, a stepwise binary logistic regression was performed. In step 1, the variables of the original Yap et al. (2013) study – driver seat space, length, and status – were included. Whereas car length and status were unrelated to any type of parking violation, the probability of parking violations increased with increasing driver seat space (OR = 1.47, $p = .005$).

In step 2, we added car price as an additional covariate. Overall, the model including driver seat space, car price, car length, and brand status predicted 'legally parked' cars versus 'illegally parked' cars better than chance ($\chi^2(4) = 30.42$, $p < .001$). As can be seen in Table 2, car length (OR = .89, $p = .43$) and car status (OR = .86, $p = .22$) had no significant influence on the probability of parking violations in step 2. Controlling for car price (OR =1.65, $p = .01$), driver seat space was still a significant predictor of parking violations (OR =1.38, $p = .02$). The odds of parking violations increased 1.38-fold for every standard deviation increase in driver seat space ($SD_{driver\ seat} = 0.27\ m^3$); and increased 1.65-fold for every standard deviation (SD) increase in car price ($SD_{car\ price} = 11{,}213€$). Specifically, at one standard deviation above the mean in driver seat space, the probability of a parking violation increased from 57 to 62%.

Table 1. Descriptive statistics and correlations among driver seat space, and the covariates car price, car length, and brand status.

	Mean	SD	1	2	3
1. Driver Seat Space	1.74 m^3	0.37 m^3			
2. Price	20,359 €	11,213 €	.61*		
3. Length	5.19 m	0.41 m	.78*	.83*	
4. Status	4.49	1.05	.25*	.65*	.42*

*$p < .01$ (2-tailed).

Table 2. Results of a stepwise binary logistic regression, regressing driver seat space on the dichotomous outcome "parking violation" (yes/no).

	B (SE)	Odds Ratio (95% CI)
Step 1[a]		
Constant	.02 (.09)	
Driver Seat Space	.39* (.14)	1.47 (1.12–1.92)
Length	.05 (.14)	1.05 (0.80–1.38)
Status	.05 (.10)	1.05 (0.87–1.28)
Step 2[b]		
Constant	.21 (.09)	
Driver Seat Space	.33** (.14)	1.38 (1.05–1.83)
Length	−.12 (.15)	.89 (0.66–1.20)
Status	−.16 (.13)	.86 (0.67–1.10)
Price	.50*** (.20)	1.65 (1.11–2.46)

B: regression coefficient; SE: standard error.
[a]Model $\chi^2(3) = 22.49$, $p < .001$, $R^2 = .03$ (Hosmer & Lemeshow), .04 (Cox & Snell), .07 (Nagelkerke).
[b]Model $\chi^2(4) = 30.42$, $p < .001$, $R^2 = .04$ (Hosmer & Lemeshow), .06 (Cox & Snell), .08 (Nagelkerke).
*$p = .005$.
**$p = .022$.
***$p = .013$.

4. Discussion

Similar to the findings of Yap et al. (2013), our study shows that driver seat space predicts the likelihood of parking violations. This effect could be replicated in a different cultural (Germany vs. US) and urban setting (the rural town of Offenburg vs. the metropolis New York City) focusing on a broad variation of parking violations identified by professional inspectors. The effect statistically persisted, even when controlling for car brand status, car length, and car price, the latter of which is also a significant predictor for parking violations.

These findings suggest that driving behaviour and traffic safety may not only be influenced by interactions between the person behind the wheel and the design of control interfaces, but also by the spatial layout of the driver's car cockpit. Further research into the effect of driver seat space on behavioural processes (eg body postures, risk taking, and violations) might inform future HF/E approaches to cockpit design. Relatedly, our results imply that cockpit design should move beyond focusing on the standard error categories of slips, lapses, and mistakes, and start paying attention to violations. Although ample studies investigate the relationship between psychological factors and traffic violations (Ba et al. 2016), there are only few HF/E studies on the effect of cockpit design on traffic violations to date (Aliane et al. 2014). The present study suggests a new avenue for HF/E to systematically investigate traffic violations in relation to the spatial dimension of cockpit design. More such studies may have the power to advance the current understanding of traffic violations by complementing psychological sources of violations with those that are located in the environment (Reason 1990).

We are aware that the behavioural effects of body postures are fiercely debated in the literature. Given that this debate is ongoing, there is no clear-cut explanatory account for our results. But even if we cannot explain the effect of body postures on parking violations with our observational design, our results may help trigger additional research for a better understanding of the empirical findings related to traffic violations.

Our study included additional control variables (ie car price) compared to the original study by Yap et al. However, there are also other variables, which should be considered in future studies. For instance, tall or heavy drivers will have different individual seat spaces compared to short and slender drivers. Also, individual seat configuration, that is, whether a seat is adjusted closer to or further away from the steering wheel, influences individual seat space and, therefore, body postures. Moreover, Carney, Cuddy, and Yap (2015) discuss that also the time a person remains in a certain posture may change its effects. Whereas experimental manipulations of body postures forced participants to hold a posture one minute (Carney, Cuddy, and Yap 2010) or three minutes (Ranehill et al. 2015), it can be assumed that participants in our study did not 'hold' but selected a posture that felt comfortable or natural, potentially for an extended period of time. Clearly, more research is needed to work out both the magnitude and the causal explanations of body posture effects as well as their relevance for cockpit design. Our results imply that it is worthwhile investigating the thus far under-researched impact of driver seat space on traffic behaviour. HF/E is well equipped to follow up on these findings.

ORCID

Felix C. Meier http://orcid.org/0000-0002-7156-3527
Markus A. Feufel http://orcid.org/0000-0003-0563-8831

References

Aliane, N., J. Fernandez, M. Mata, and S. Bemposta. 2014. "A System for Traffic Violation Detection." *Sensors* 14 (11): 22113–22127. doi:10.3390/s141122113.

Ba, Y., W. Zhang, Q. Peng, G. Salvendy, and D. Crundall. 2016. "Risk-Taking on the Road and in the Mind: Behavioural and Neural Patterns of Decision Making between Risky and Safe Drivers." *Ergonomics* 59 (1): 27–38. doi:10.1080/00140139.2015.1056236.

Bagnara, S., and S. Pozzi. 2015. "Embodied Cognition and Ergonomics." *Journal of Ergonomics* 05 (01): e129. doi:10.4172/2165-7556.1000e129.

Barsalou, L. W. 2008. "Grounded Cognition." *Annual Review of Psychology* 59 (1): 617–645. doi:10.1146/annurev.psych.59.103006.093639.

Bhise, V. D. 2016. Ergonomics in the Automotive Design Process. Boca Raton: CRC Press. https://nls.ldls.org.uk/welcome.html?ark:/81055/vdc_100045257155.0x000001.

Carney, D. R., A. J. C. Cuddy, and A. J. Yap. 2015. "Review and Summary of Research on the Embodied Effects of Expansive (vs. Contractive) Nonverbal Displays." *Psychological Science* 26 (5): 657–663. doi:10.1177/0956797614566855.

Carney, D. R., A. J. C. Cuddy, and A. J. Yap. 2010. "Power Posing: Brief Nonverbal Displays Affect Neuroendocrine Levels and Risk Tolerance." *Psychological Science* 21 (10): 1363–1368 doi:10.1177/0956797610383437.

Census Data. 2011. Decennial Census – Census 2010. https://www1.nyc.gov/site/planning/data-maps/nyc-population/census-2010.page.

Credé, M., and L. A. Phillips. 2017. "Revisiting the Power Pose Effect: How Robust Are the Results Reported by Carney, Cuddy, and Yap (2010) to Data Analytic Decisions?" *Social Psychological and Personality Science* 8 (5): 493–499. doi:10.1177/1948550617714584.

Cuddy, A. J. C., S. J. Schultz, and N. E. Fosse. 2018. "P-Curving a More Comprehensive Body of Research on Postural Feedback Reveals Clear Evidential Value for Power-Posing Effects: Reply to Simmons and Simonsohn (2017)." *Psychological Science* 29 (4): 656–666. doi:10.1177/0956797617746749.

Gino, F., and L. Pierce. 2009. "The Abundance Effect: Unethical Behavior in the Presence of Wealth." *Organizational Behavior and Human Decision Processes* 109 (2): 142–155. doi:10.1016/j.obhdp.2009.03.003.

Hall, J. A., E. J. Coats, and L. S. LeBeau. 2005. "Nonverbal Behavior and the Vertical Dimension of Social Relations: A Meta-Analysis." *Psychological Bulletin* 131 (6): 898–924. doi:10.1037/0033-2909.131.6.898.

Norman, D. A. 2013. *The Design of Everyday Things.* Revised and expanded edition. New York, NY: Basic Books.

Peters, G. A., and B. J. Peters. 2002. *Automotive Vehicle Safety.* London: Taylor & Francis.

Piff, P. K., D. M. Stancato, S. Cote, R. Mendoza-Denton, and D. Keltner. 2012. "Higher Social Class Predicts Increased Unethical Behavior." *Proceedings of the National Academy of Sciences* 109 (11): 4086–4091. doi:10.1073/pnas.1118373109.

Ranehill, E., A. Dreber, M. Johannesson, S. Leiberg, S. Sul, and R. A. Weber. 2015. "Assessing the Robustness of Power Posing: No Effect on Hormones and Risk

Tolerance in a Large Sample of Men and Women." *Psychological Science* 26 (5): 653–656. doi:10.1177/0956797614553946.

Reason, J. T. 1990. *Human error. Cambridge [England]*. New York: Cambridge University Press.

Simmons, J. P., and U. Simonsohn. 2017. "Power Posing: *P*- Curving the Evidence." *Psychological Science* 28 (5): 687–693. doi:10.1177/0956797616658563.

Statistisches Bundesamt. 2018. "Zahlen Und Fakten – Länder & Regionen - Alle Politisch Selbständigen Gemeinden Mit Ausgewählten Merkmalen Am 31.12.2016." Statistisches Bundesamt (Destatis). https://www.destatis.de/DE/Zahlen Fakten/LaenderRegionen/Regionales/Gemeindeverzeichnis/Administrativ/Archiv/GVAuszugJ/31122016_Auszug_GV.html.

Yap, A. J., A. S. Wazlawek, B. J. Lucas, A. J. C. Cuddy, and D. R. Carney. 2013. "The Ergonomics of Dishonesty: The Effect of Incidental Posture on Stealing, Cheating, and Traffic Violations." *Psychological Science* 24 (11): 2281–2289.