Evolution of the PARRC model of driver distraction: methodologies, findings and recommendations

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ABSTRACT

The Prioritise, Adapt, Resource, Regulate, Conflict (PARRC) model of driver distraction was developed as an explorative model to capture the key factors involved in distraction from in-vehicle technology. The model aims to facilitate a systems view of driver distraction and the role that systemic actors have on the factors involved in distraction. This paper will detail the novelty of the PARRC model of driver distraction from in-vehicle technology, its development through grounded theory and further application to real world data collected from an interview study as well as a simulator and on-road driving study. The evolutionary steps the model underwent through these applications and what they reveal about the phenomenon of driver distraction is discussed. Furthermore, recommendations to practise are presented that target the actors within the sociotechnical system surrounding distraction related events that have been realised through the model and its application.

KEYWORDS

Driver distraction, In-vehicle technology, Socio-technical systems, model validation

Introduction

Driver distraction research has been a key focus within the road safety domain for many decades (e.g. Brown et al., 1969). In recent years it has been impacted by the development of the digital age that has enabled technology to become increasingly prominent in the vehicle. The integration of in-vehicle displays in addition to the increasing prevalence of nomadic technologies that drivers bring in to the vehicle present multiple sources of distraction that were not common place until relatively recently. Mobile phones are a notable technology whose development and popularity have caused problems for road safety (see McCartt et al., 2005 for a review). Yet, the popularity of tablets, wearable technology and mp3 players also provide additional information for the driver to interact with while driving, if they so desire.

Road safety legislation has tried to tackle the issue of driver distraction with penalties in the form of fines and points on the licenses of drivers that are caught driving distracted. Legislation must adapt to match the current social and technological influencers of the road transport system. Yet, as technologies develop at a rapid pace, it is difficult for policy to regulate its use and adequately control it (Leveson, 2011). Since the initial ban on the use of mobile phones by drivers in the UK in 2003, the fine allocated to law breakers has increased from £30 to £60 (2007), then to £100 (2013) before reaching £200 and 6 penalty points in 2017. Despite this, the media obtained data from the Press Association under the Freedom of Information (FOI) Act that stated approximately 6000 drivers were caught using their devices in the four weeks after the recent 2017 legislation came into effect. This highlights that legislation is no 'quick-fix' method and the difficulties of keeping pace with technological developments. To address this, other safety management domains have looked towards alternative methods of avoiding accident causation that go beyond the role of the individual, towards the complex sociotechnical system within which behaviour occurs (e.g. Stanton & Walker, 2011). These views of accident causation state accidents are not solely the result of the interactions of the individual, but explore the other elements that interact with them. The Prioritise, Adapt, Resource, Regulate, Conflict (PARRC) model of distraction was the first attempt within the literature to develop a model of distraction that enabled the influence of systemic actors over the emergence of distraction related events to be realised. This paper will discuss the development of the PARRC model of distraction (Parnell et al., 2016), focusing on the evolution of the model from its conception to its application to data collected from a range of different methodologies. The resulting insights that inform countermeasures that can holistically target the issue of driver distraction are discussed.

Stage 1. Grounded theory: model development

Grounded theory is used to explore the underlying principals, mechanisms and behaviour of a phenomenon through studying the literature that it originates from (Glaser & Strauss, 1967). This makes it a useful tool in developing theories and models with conclusions drawn from an array of different sources (Rafferty et al., 2010). It was therefore used to expose the key factors that are discussed in the literature on driver distraction from technological devices and the direction of significant interactions between them to reveal how driver distraction may be modelled.

Method

A document analysis was conducted to systematically search, refine and review the literature, including the imposition of a search criteria and a meticulous review process (for further detail see Parnell et al., 2016). This succinctly reduced the number of items for inclusion in the review from 393 to 33. These articles were then read in detail, compared and reviewed in an iterative process to seek out themes, factors and interconnections. An initial 25 key factors were identified from the literature. These were then again reviewed and refined to establish the top five prominent factors from within the literature; ‘Goal priority’, ‘Adapt to demands’, ‘Resource constraints’, ‘Behavioural regulation’ and ‘Goal conflict’. Definitions of these factors are given in Table 1.

Table 1: The PARRC factors of distraction

Factors	Definition
Goal Priority	The multiple goals drivers face cannot be completed simultaneously; they need to be prioritised in accordance with goal hierarchy. It is important that the priorities match the current demands to maintain safety.
Adapt to Demands	The increased mental and physical demand associated with engaging with secondary tasks while driving requires adaption of either the primary or secondary task, or both.
Resource Constraints	Attentional resources are finite; successful driver behaviour involves manipulating resources to enable their efficient distribution between tasks and according to the situational demands.
Behavioural Regulation	The self-management of attention, effort, attitudes and emotions to facilitate goal attainment.
Goal Conflict	The existence of two or more goals that come into competition with each other such that both cannot be completed concurrently without disrupting one another.

From a socio-technical perspective, safety arises from the complex interactions between actors and elements within a system (Leveson, 2004). Therefore, the study of the interconnections made between elements is important when understanding how safety may be upheld, as well as how accidents may occur. The empirically tested connections and associations made by authors when relating concepts to one another were analysed. The links made between each of the factors determined the strength of association between them in the literature. These were used to develop the interconnections of the PARRC factors and form the PARRC model of distraction (Figure 1a).

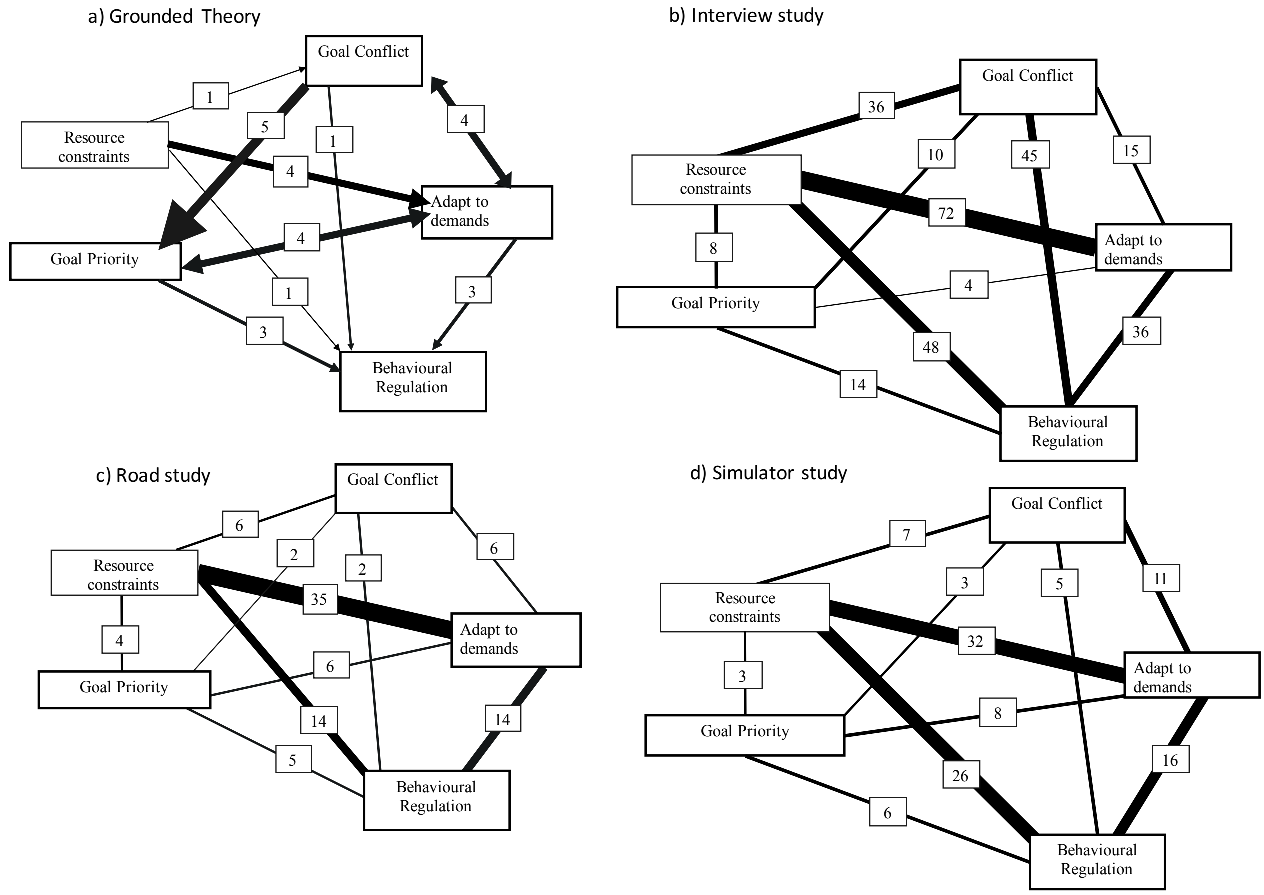

Figure 1: The developmental stages of the PARRC model through data collected from a) grounded theory, b) an interview study, c) a road study and d) a simulator study

Findings

Grounded theory methodology enabled the PARRC model to be developed and 'grounded' within the literature. It therefore represents research themes and interactions that have previously been studied. Some of the interconnections were referenced frequently (e.g. 'goal conflict' to 'goal priority' and others were absent (e.g. 'resource constraints' to 'adapt to demands'). Yet, further assessment and validation of the model was required to ensure that the connections were fully explored and that the literature was representative of real-world behaviour.

Stage 2. Semi-structured Interviews: model validation

While the literature had frequently sought to monitor the drivers' workload and visual attention, it was less concerned with the reasons why distraction occurred in the first place. The application of semi-structured interviews captured the drivers' perspective on why they engage with technologies.

Method

Interviews were conducted with 30 UK drivers (15 males, 15 females), aged 22-60 years. Participants were asked to rate their likelihood of engaging with 22 different technological tasks relating to a sat-nav, hands-free phone, in-vehicle entertainment system and a hand-held mobile phone. They were also asked to openly discuss their reasoning behind why they may be more or less likely to engage with each of the technologies. This gave an insight into the factors that they deemed important to their decision to engage with the technological tasks. The discussion was audio recorded and transcribed. An inductive thematic analysis of the transcripts provided a rich insight in the data set as a whole and identified naturally occurring themes informed by drivers themselves. The themes that the drivers discussed were then contrasted to the factors that emerged from the literature in the development of the PARRC model. The methodology and data analysis are detailed in Parnell et al. (2018).

The inductive thematic analysis followed Braun and Clarke’s (2006) guidelines and utilised the qualitative research tool Nvivo11. The bottom-up approach meant that descriptive codes were first derived from the transcripts using in-vivo codes, and statements were coded to multiple themes where appropriate. This extensive list of descriptive codes was then aggregated into semantic, higher level codes that captured the meaning of multiple themes. It then became evident to the researchers that the semantic themes could be attributed to the systemic actors. Four main systemic actors were attributed to the semantic themes: the driver, the wider context, the infrastructure and the task. A hierarchical thematic framework comprised of descriptive, semantic and systemic themes was generated to represent an exhaustive list of reasons that influenced the drivers’ decision to engage with the technologies. This provided a useful tool kit to compare to the key factors and interconnections that were developed and grounded within the academic literature that the original PARRC model was generated from.

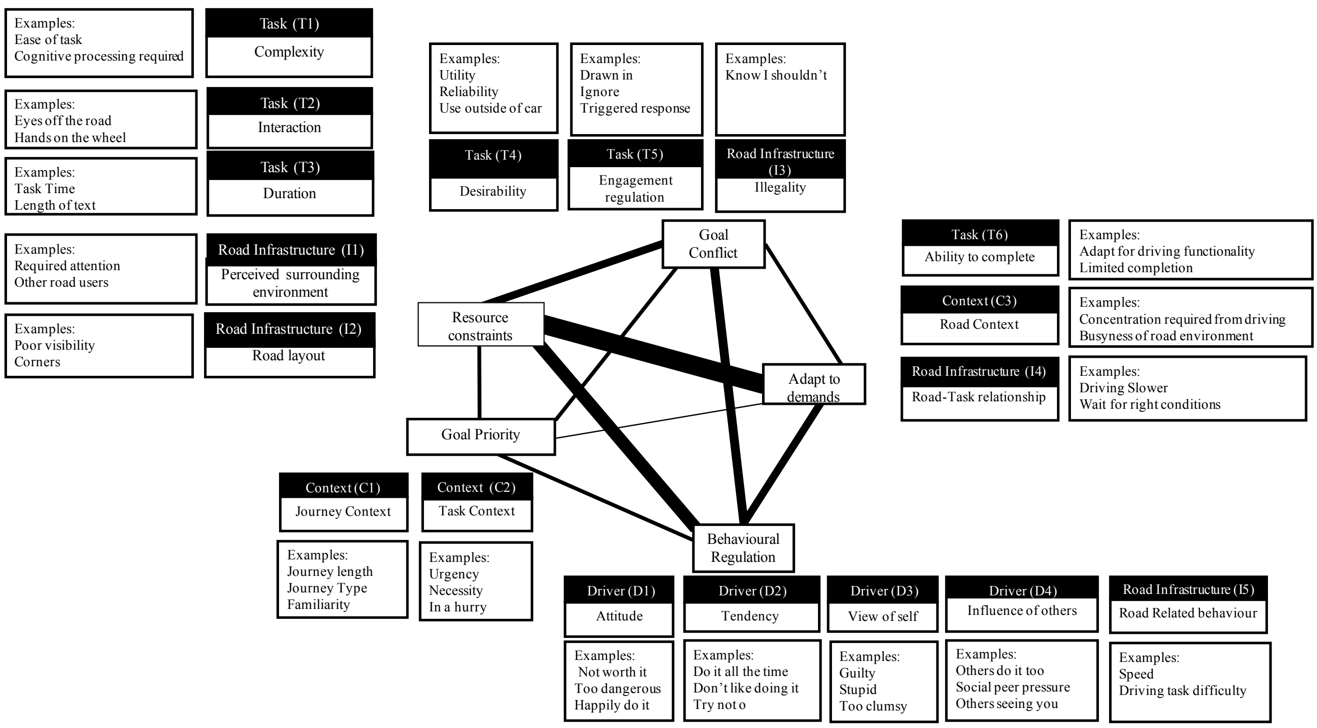

Figure 2: Application of the inductive thematic framework to the PARRC model.

Similarities to the PARRC model were found, yet it was evident that there were concepts that extended the limited range of variables that were found in the literature. The sematic themes were coded to the PARRC factors, as can be seen in Figure 2. Interconnections made between the factors, as discussed by the drivers, were also an important aspect of validating the PARRC model. Once the themes of the framework had been coded to the PARRC model factors, the connections that the drivers had referenced could be analysed with a Nvivo11 matrix query. Single excerpts of the transcripts were coded to multiple themes (Braun &Clarke, 2006) and it was evident that the complexity of the phenomenon often meant that drivers were referencing multiple themes concurrently. A matrix query quantified the connections identified between the themes that were coded to the PARRC factors. The strength of the interconnections made in the literature could then be compared to those discussed by drivers in the interview. The emerging structure of the PARRC model from the semi-structured interview study is shown in Figure 1b.

Findings

The frequency of referenced interconnections is greater in the model derived from the interview study due to the rich data source that semi-structured interviews generate. The specificity of research within the literature limits the frequency of connections but it does allow the interactions to be directional as researchers are actively seeking to observe the direction of an effect of one variable on another. Analysis of the interview data was more concerned with the prevalence and co-occurrence of factors in the data that was derived from drivers self-generated reports.

The interviews generated a connection that was not previously found in the literature: 'resource constraints' to 'adapt to demand'. The absence of the connection in the literature was considered to reflect the strong relationship between 'goal conflict' to 'goal priority' in the original model which reflected the frequent assessment of resolving goal conflict through prioritising. Yet, the interviews evidenced that drivers were less concerned with prioritising their goals and more motivated to adapt their behaviour in line with the attentional resources they had available to facilitate multiple goals concurrently. Analysis of the transcripts relating to this connection suggest drivers stated they would lend some attention to a task initially to determine if it should require further prioritisation or if it could be ignored. This was particularly evident when discussing their likelihood of reading a text message while driving. E.g. "*I would never open up a whole message, but I might glance down and look at who it is from at least and what is written on it".* The reduced proportion of references linking the 'goal conflict' and 'goal priority' factors in the interview based model is contrasted to a stronger interconnectivity of the 'resource constraints' factor to other factors, predominantly the connection to 'adapt to demands'. For example, one participant stated how the demands of the environment influence their attentional focus "*So the picture that you've got has lots of cars on the side of the road and houses and I'd be thinking, "Ah a car is going to pull out in front of me" or, "I'm going to get very close to a car" so therefore 100% needs to be on the road at that point."*

The connection between 'goal conflict' and 'behavioural regulation' was also of interest. The original PARRC model suggested the connection represented a triggered response to safety critical points that caused drivers to realign their goals. Yet, reviewing the interview transcripts that were coded to this connection highlighted the role that drivers' attitude played in regulating engagement with tasks that may conflict with the driving task. Many drivers held very strong attitudes against interacting with the technologies while driving that influenced their behaviour, in a top-down manner. For example, "*I think you'd be crazy to try and enter something into a sat-nav"*. Some drivers also specifically placed their phone out of reach while driving. It also suggests that attitude change may be a possible countermeasure to driver distraction, although caution is issued as not all of the drivers' attitudes were comparable.

The semi-structured interview study provided a rich data set to explore the themes that were initially generated from the literature and contrast them to concepts that drivers deem important to their decision to engage with technology while driving. This both assisted in validating the PARRC factors and extending their interconnections. Yet, further research was required to capture the drivers' intention within the context that interaction with in-vehicle technology occurs.

Stage 3. Simulator and on-road studies: model validation.

Simulators have become a popular method for assessing driver distraction which can be attributed to their low risk environment and high level of control. Their ability to capture the drivers' decision to engage with distractions was explored in contrast to a realistic road setting.

Method

Twelve participants (six females and six males) were recruited as a sub-sample from the interview study. Participants were given four hypothetical scenarios that required them to engage with technology while driving: make a phone call, read a text message, enter a destination on a sat-nav and change the song/radio. Participants were asked to state if they would be willing to perform each of the tasks at predetermined points on a route that encompassed a motorway, an A-road and roundabouts. Drivers were asked to provide verbal protocols of their decision making process in response to being asked their intention to engage in the four scenarios. They were given extensive training in providing verbal protocols. Participants drove in an instrumented vehicle on the roads and in a simulated version of the route with a full-car driving simulator while providing the verbal reports on their intention to engage. The thematic framework developed form the interview data was used to deductively code the drivers' reports using Nvivo11.

Findings

Driver intention on the road was found to strongly correlate to their intention to engage in the simulator, as was the frequency of references made to the themes coded to the thematic framework. Yet, there were a number of references to the influence of other road users on the drivers' decision to engage that were not evident in the semi-structured interviews. The systemic key theme 'Other road users' was therefore added to the thematic framework. The nature of the statements that were coded to this theme were associated with the 'adapt to demands' factor of the PARRC model due to the demands that were involved in managing the interactions with other road users. Nvivo11 was again used to code statements to the thematic framework and matrix queries were run to explore the interrelations between themes in order to develop the PARRC models in Figure 1c and 1d. The similarities in the content of the drivers' verbalisations across both conditions can be seen. They also have much in common with the connections found in the interviews, primarily the heighten references connecting 'resource constraints', 'adapt to demands' and 'behavioural regulation' and the comparatively reduced connection between 'goal priority' and 'adapt to demands'. This suggest that drivers are able to accurately report their intentions to engage in an interview setting to a level comparable to when they are actually driving. Yet, it also highlights the importance of obtaining data to validate and expand theoretically developed models across different research settings.

Discussion

This paper has presented the development of a model of driver distraction that aimed to capture the factors that comprise the behaviour and explore the influence of wider systemic actors on the emergence of distraction related events. The PARRC model was born out of the findings and themes discussed in the current literature surrounding the drivers' interaction with technological sources of distraction. Therefore, the key factors and interconnections that were identified required further validation with data derived from drivers themselves. The application of findings from semi-structured interviews (Parnell et al., 2018) and an experimental study comparing both a simulated and a real road environment expanded the theoretically derived model. This sought how drivers' view their behaviour and their decision making processes to assess the influence of systemic factors, predominantly; the context, other road users, the driver, the task and infrastructure. The differences in the model that were found when applying qualitative reports of the drivers own views on their engagement with distractions in contrast to those studied in the literature highlight some key issues. The presence of a connection between ‘resource constraints’ and ‘goal priority’ in the drivers’ discussions across the interview and driving studies suggest that the literature from which the original PARRC model was developed may be lacking. The connection suggests that drivers may lend some resources to the secondary task to determine its priority before completing the task. This further supports the alterations in the models developed through the interview and driving studies that emphasise the drivers’ adaption of their behaviour to integrate the secondary task with the driving task through manipulating their behaviour and available resource, (as shown through the strong connections between ‘resource constraints’, ‘behavioural regulation’ and ‘adapt to demands’ in Figure 1b, c and d). Conversely, the original PARRC model (Figure 1a) states the importance of the connection between ‘goal conflict’ and ‘goal priority’ that suggests a more straightforward decision making process. These differences highlight the important contribution that the qualitative analysis of drivers’ own perceptions and decision making processes have to the literature. It also reveals the opportunity for alternative countermeasures to those traditionally employed which harness the old, individual view of driver distraction.

Recommendations

The utility of developing a novel model of distraction that highlights the importance of systemic factors is to assess the potential for novel countermeasures. Previous attempts to mitigate driver distraction, particularly in response to rapidly developing technology, have relied on the use of legislation that targets the individual. Yet, taking a systems view of the issue suggests that focusing solely on the individual is not effective, instead the interaction of a host of other actors within the environment must be realised. The evolutionary processes of the PARRC model has found key factors of distraction that are influenced by, and interact with, key systemic actors. These actors should be targeted with novel countermeasures.

Importantly, the original PARRC model developed from the literature highlighted the role of prioritising conflicting goals so that only one is focused on at one time. This research is reflected in legislation that prohibits specific devices (e.g. mobile phones) to avoid goals from conflicting. Yet, the research presented in the interview and driving studies suggests the drivers’ behaviour is more complex than this as they strive to integrate secondary tasks with the driving task through adapting their behaviour and regulating their engagement in line with their available resources. The way in which drivers can facilitate this is through their interactions with actors within the sociotechnical system. Therefore, it is these actors that should be targeted. The distinction between the literature and the drivers own reports raises questions on the governments funding of research and initiatives that are justified by the literature as they may be subject to gaps in knowledge. There is a need for research that is able to capture the drivers own decision making processes and the key actors involved in it to incorporate these into effective countermeasures.

The risk management framework details the hierarchical levels of a socio-technical system and can be used to inform the actors that comprise a system (Rasmussen, 1997). Assessment of the systemic actors that were identified from the interview and driving studies were reviewed to determine the elements of the system that may be targeted for distraction countermeasures. The distribution of these actors across the hierarchy is shown in Figure 3.

	Driver	Infrastructure	Task	Context	Other road users
International Committees		United Nations e.g. The general assembly, ECE Regulations	International standards e.g. ISO, SAE World Health Organisation (WHO)		World Health Organisation (WHO)
National Committees	Culture, Media & Sport Committee	Transport Select Committee	Science & Technology Committee British Standards Organisation		British Standards Organisation
Government	Department for Culture, Media & Sport	Department for Transport			Department for Culture, Media & Sport Department for Transport
Regulators	Media Road Safety Charities	National Road Safety Policy e.g. The Highway Code, Road Traffic Act	UK HMI Design Guidelines e.g. BSI code of practise UK Vehicle manufacturing/ design standards		National Road Safety Policy e.g. The Highway Code, Road Traffic Act UK Vehicle manufacturing/ design standards
Industrialists			Aftermarket /portable device manufacturer Telecommunication Association Phone manufacturer Vehicle manufacturers	Research centres	Research centres Insurance Companies
Resource providers	Driver education/training providers		Aftermarket device designers Driver assistance device designers Phone designers In-vehicle interface designers		
End User	Passenger(s) Other Road User(s)			Contacts on media devices	On-board sensors
Equipment & Environment		Road type Road features	In-vehicle technology (In-built or portable)	Environmental conditions	Road features

Figure 3: Application of the inductive thematic framework to the PARRC model.

The location of key actors within the hierarchy is important. Those higher up can facilitate widespread change at lower levels, whereas those lower down can have a more direct influence on the driver and their interaction with the environment. Figure 3 reveals the important actors at the top levels of the system that are involved in setting the standards and informing effective legislation that can influence the driver, as well as providing improved infrastructure and technology standards. Lower down in the system, the role of device manufacturers is also apparent as it is highlighted that manufacturers must consider the impact of the information they permit the driver to have access to in the vehicle.

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