RE-THINKING FLOW: A COGNITIVE SCIENCE MODEL
AND APPLICATIONS TO VIDEO GAME DESIGN

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Abstract:
Flow is a concept that takes a prominent place in video game design theory and practice, as well as in other fields, but the phenomenon and its cognitive components are poorly understood scientifically. In this paper I present a cognitive science-based theory of the experience of flow. For this, I identify key theories and concepts from the literature and formulate two hypotheses about the cognitive processes underlying flow’s phenomenology. Based on these hypotheses, I develop a model which I then use to propose a number of design heuristics for eliciting flow in video games. Finally, I consider implications for the currently prevalent interpretation of the phenomenon and discuss the need to test my theory and design heuristics with empirical studies.

Keywords:
Flow; optimal experience; cognitive science; video games; design heuristics; unconscious processes.

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1. INTRODUCTION

Existence is a complicated matter. Whether we like it or not, life is a relentless bombardment of information in the shape of sensory stimuli. Sights, sounds, smells, tastes, feelings of pressure, texture… all of them provide hints about what is actually happening out there, beyond our isolated minds. But this information is too much to process in its entirety and does not come ordered. Thus, we fabricate narratives that help us make sense of it by inventing categories, hierarchies and relationships that we assign to the chunks of data coming across time and space; we gather raw information and turn it to our advantage by infusing it with a meaning especially tailored to our biological and sociocultural needs.

These stories we tell ourselves to make sense out of existence provide us with goals and ways to achieve them, but they come at a price: they require that we spend colossal amounts of time evaluating, judging, prioritizing, reasoning, planning, projecting and deciding. So much of our lives are devoted to these that we forget what it feels like to experience stimuli in its raw form, without the intermediacy of thoughts. We effectively become masters—and slaves—of abstraction, as we get used to living with an inner voice that interprets everything we sense and will not shut on command.

This paper is about those times when the voice finally shuts, and we are taken back to a primal state with no narratives and no meaning. In a world with an ever-increasing demand on abstraction and scenarios full of sophisticated choices, being released from this burden, if only for a moment, feels awesome. We finally let go of the steering wheel and get to become a passenger, free to fuse with the outside view. No intermediary, no destination. By being stripped of our most distinctive human trait we become our senses, and thus transcend.

Most of us have experienced this at some point: when playing an instrument, dancing, practicing sports, meditating or playing a video game, we forget all our concerns and desires, we act without thinking, and time is suspended. Nothing but the experience of raw stimuli remains.
These experiences were recognized by eastern contemplatives thousands of years ago, but they did not seem to generate much interest in western academia until relatively recently, with Csikszentmihalyi’s research on what he would call “flow” experiences (1975, 2014). Closely tied with the Positive Psychology movement, the concept of flow has had a big impact on the way experiences are understood and designed for, regardless of whether they are intended for leisure or for work (Csikszentmihalyi & Lefevre, 1989). In particular, flow has become a very important concept within the domain of video games, as designers and researchers look for ways of eliciting the state in order to produce engaging experiences (Chen, 2007). However, the widespread traditional definition of flow developed by Csikszentmihalyi (2014) lacks in precision and does not provide rigorous scientific theory to account for its proposed phenomenological and activity-related elements, listed in Table 1.

Inspiration for this project comes from two observations about the traditional characterization of the phenomenon:

- Flow’s phenomenology (today associated with Table’s 1 elements No. 1 to 6) was first described before the explosion in cognitive science knowledge that allowed for vast progress in the understanding of the mind and its connection with brain activity. As a result, foundational work that is frequently used as a framework by the academy and the industry alike focuses on describing flow’s experience without deepening on the mechanisms underlying it.
Given the diversity of ways in which people experience the state, each type of activity may have its own set of flow-inducing characteristics (today circumscribed to Table’s 1 elements No. 7 to 9).

A theoretical mapping of concepts from cognitive science might allow for a model that offers a possible explanation for flow by reducing it to the fundamental processes underlying its phenomenology. Such a model could be the basis for a set of design heuristics to elicit flow states—in video games and other activities—, improving existent explanations of why, if at all, currently proposed heuristics are important. Furthermore, the model could represent a first step towards the identification of the phenomenon’s neural correlates, which could in turn contribute to the development of procedures to measure at least some of its constituents and reduce reliance on self-reporting methodologies. As a result, this work could be a factor in the advancement of the formal study of flow and video games, while helping designers create more engaging experiences.

Grounded in contemporary cognitive science this paper proposes a reductive account of flow, arguing that the phenomenon should be understood from an information-processing perspective. In this context, I post two interrelated hypotheses about its nature that basically describe (1) what information should be processed—i.e. where attention is directed to—and (2) how it should be processed—i.e. which information is consciously/unconsciously processed—for the phenomenal experience to emerge:

1. Flow requires working memory (WM) to be fully and uninterruptedly controlled by information corresponding to the stimuli originating from the activity in question. As a result, no WM capacity must be allocated to internal states.

2. Flow is a state in which stimuli are consciously processed (there is an associated phenomenal experience), while actions triggered by these are unconsciously processed (they are executed automatically, without thought, awareness, or explicit memory). Consequently, flow experiences resemble “trance” states that can only be fully recognized as such a posteriori.

In this paper I exhibit a review of the theory supporting these hypotheses as well as a model stemming from them. Based on this model, I provide an explanation for some of
the phenomenology elements from the traditional characterization, while at the same time I reject or put into question others. Furthermore, I derive from the model a set of video game design heuristics for eliciting the state. Lastly, I discuss the model’s implications for the study of flow as well as the need to test presented hypotheses and heuristics with empirical studies.

In short, the goal of this paper is to propose a scientifically-grounded explanation for how is it that flow states emerge and for why they feel the way they do, while suggesting ways to elicit these states within the context of video games.

2. THEORETICAL BACKGROUND

2.1. INTRODUCTION

Behaviorism as a school within the larger field of psychology emerged in the late 19th century and thrived until mid-20th century. Its focus was to understand how different types of measurable stimuli influenced observable actions. In many ways behaviorism contributed to taking psychology into the field of science, making it a response to previously dominating methods that relied heavily on introspection. However, in the pursuit of acquiring precise and objective data, behaviorists tended to think of internal processes as a “black box”: abstract motivations, feelings, awareness and consciousness were thought to be inaccessible to scientific study (Kandel, 2013). The last decades have shown a steady progress in technology, methodology and theory that has contributed to take the analysis of internal processes (and experience) into the scientific realm (Smallwood & Schooler, 2015). Although there is still a long way to go, the mind has now begun to be understood through the scientific method.

In this paper I aim to propose an explanation for a phenomenon defined by its experiential quality. This is without doubt a complicated enterprise and in order to understand why, it is important to have a basic understanding of the computational theory of mind (CTM; McCulloch & Pitts, 1943). Under this theory, the mind is equal to the flow of information generated by the nervous system, which operates under a Turing-style of computation (Turing, 1937). This popular proposition has deep
implications on the nature of the mind and all the processes associated with it, including attention, memory, reason, emotion, decision making, language formation, and even consciousness, because it suggests that all can be reduced to the computation of information. Some of the concepts posted both by the followers and detractors of the CTM will be explored in the following section.

I argue that flow is not a process taking place in our brains, but a state of consciousness emerging from the behavior of fundamental cognitive mechanisms. As mentioned, I contend that a certain configuration of information processing lies at the core of the phenomenon. In the following sections I review the theories that support this claim, in addition to other relevant concepts.

2.2. SELF-AWARENESS & CONSCIOUSNESS

In Kandel’s Fifth Edition of Principles of Neural Science it is mentioned that consciousness is “ordinarily thought as a state of self-awareness” and that, as a result, it shares three essential features with this state: unity, intentionality, and subjectivity (2013, p. 385). Before describing these, it is important to notice that this paper considers self-awareness to be one out of many possible states of consciousness, and not the other way around. To evaluate this claim it is first essential to understand what is meant by self-awareness.

2.2.1. SELF-AWARENESS

Being self-aware means to become the object of one’s own attention (Duval & Wicklund, 1972) by identifying processes and storing information related to one self (Morin, 2011). For this, we need to perform a “metacognitive representation of any mental state with a propositional content such as beliefs, attitudes, desires, and experiences” (Schmitz, Kawahara-Baccus, & Johnson, 2004, p. 941). In other words, self-awareness occurs when recognizing that a stimulus/behavior is perceived or when evaluating emotions and thoughts. Self-awareness is necessary for guiding our decisions and behaviors, and for developing theories to make informed guesses about the contents in others’ minds (a process known as theory of mind) (Schmitz et al., 2004).
Furthermore, without it our sense of being separate from the environment is diminished (T. S. Duval, Silvia, & Lalwani, 2001; Frantz, Mayer, Norton, & Rock, 2005).

In the context of the highly influential *self-consciousness scale* (Fenigstein, Scheier, & Buss, 1975), “self-consciousness” was originally used to refer to specific types of self-awareness. However, the two terms are frequently used without distinction across the literature, as is the case with this paper. Nomenclature aside, given the definition provided it seems reasonable to state that self-awareness cannot be a condition for consciousness. A number of arguments support this claim.

First, only a handful of animal species have passed the so called “mirror test” in which an animal is tested for visual self-recognition as an indicator of self-awareness (Gallop, 1970; Prior, Schwarz, & Güntürkün, 2008). Furthermore, most infant humans less than 18 months old do not pass the test (Bard, Todd, Bernier, Love, & Leavens, 2006). If consciousness was understood as a state of self-awareness then these results would suggest that baby humans, dogs, cats and monkeys are not conscious entities, which does not seem probable. That being said, the use of self-recognition as an indicator of self-awareness has been questioned (Morin, 2002), so these results may not be enough to make an assertion over the connection between self-awareness and consciousness.

A second and more effective argument stems from the idea that “the self” is nothing more than a narrative we use to make sense out of a dynamic system without a constant. In the words of philosopher Thomas Metzinger (2005):

> No such things as selves exist in the world. For all scientific and philosophical purposes, the notion of a self—as a theoretical entity—can be safely eliminated. What we have been calling "the" self in the past is not a substance, an unchangeable essence or a thing (i.e., an "individual" in the sense of philosophical metaphysics), but a very special kind of representational content: the content of a self-model that cannot be recognized as a model by the system using it. (...) At least for all conscious beings so far known to us it is true that they neither have nor are a self. Biological organisms exist, but an organism is not a self. Some organisms possess conscious self-models, but such self-models certainly are not selves—they are only complex brain states—. However, if an organism operates
under a transparent self-model, then it possesses a phenomenal self. The phenomenal property of selfhood as such is a representational construct: an internal and dynamic representation of the organism as a whole to which the transparency constraint applies. It truly is a phenomenal property in terms of being an appearance only. (p. 3)

This argument is a direct attack to the fallacy of the homunculus (from Latin, little person): the idea that there is a constant essence witnessing and manipulating thoughts, actions and perceptions; a thinker of thoughts that is carried from one moment to the next. As Metzinger implies, the homunculus fallacy originates in the fact that “the self” exists from a phenomenological perspective: because we feel it we conclude that it must be real. However, this is an illusion and we only experience the feeling of being a self when the corresponding representational model is posted in consciousness. In this light self-awareness cannot be a condition or a synonym of consciousness because “the self” is nothing more than a content of our conscious experience. This proposition not only is shared by many other philosophers of mind and–mostly Buddhist–contemplatives (see Harris, 2014), but also is supported by current neuroscience knowledge.

Studies conducted in the last two decades consistently suggest a positive correlation between self-representational processes and activity in the medial prefrontal cortex (MPFC) and the posterior cingulate cortex (PCC) (Moran, Kelley, & Heatherton, 2013; Raichle, 2015). This agreement is contrasted by what seems to be some discrepancies regarding more detailed correlations. In particular, there are studies that suggest that the dorsal MPFC (dMPFC) is more closely associated with self-reference and the ventral MPFC (vMPFC) to emotion processing (Gusnard, Akbudak, Shulman, & Raichle, 2001; Schmitz et al., 2004), while others pose that it is vMPFC activity that shows a higher correlation with self-referential processes, with dMPFC being more associated with others-related judgement (Denny, Kober, Wager, & Ochsner, 2012). Furthermore, a meta-analysis of 87 studies performed by Qin and Northoff (2011) pointed to the perigenual anterior cingulate cortex (pACC) as the area responsible for self-related processing of information while stating that MPFC and PCC were functionally unspecific since their activity increased both when subjects were presented with self-specific and familiar stimuli.
Regardless of their specific function, these brain regions form part of the so-called default mode network of the brain (DMN) (Raichle et al., 2001). Studies have shown that the DMN’s activity varies greatly depending on where attention is directed, and this includes areas associated with self-representation. In effect, activity decreases in the MPFC (Goldberg, Harel, & Malach, 2006; Gusnard et al., 2001) and in the PCC (Johnson et al., 2002) when subjects perform sensory-demanding or semantic tasks vs. self-referential tasks. Furthermore, clinical cases suggest that some lesions to the frontal lobes can result in deficient self-representation—subjects showed lack of sense of unity when describing experiences and lack of intentionality in behavior, possibly driven by diminished self-interest—without impairment of other cognitive processes (Stuss & Alexander, 2000).

Exposed philosophical and scientific arguments support the idea that self-related representations are not a condition for subjective awareness and that self-awareness is not a constant mental state. A representational model of the self must be evoked into consciousness for us to feel self-aware, and for this attention must be at least partially directed towards internal states so metacognition can occur (see Section 2.4.1).

2.2.2. CONSCIOUSNESS

Having argued that self-awareness is a state of consciousness, it is important to clarify what exactly is understood by consciousness and why it is important for the study of flow.

The term consciousness is frequently used to refer to a variety of phenomena that includes awareness, self-awareness, arousal, focus of attention, integration of information through cognition (named “unity” in the previous section), deliberate control of behavior (named “intentionality”), and the ability to discriminate, categorize and react to environmental stimuli. It is all of these that David Chalmers pointed out to be part of “the easy problem of consciousness” in his seminal work titled “Facing up the problem of consciousness” (1995). According to Chalmers, explaining all of these is “easy” in the sense that they can be reduced to their fundamental components by using the traditional scientific method. In his terms, these are all cognitive abilities and functions that can be explained in terms of computational or neural mechanisms.
Even though the “easy” problem is one that may take humanity several decades (or even centuries) to solve in its entirety, there is another one that may prove to be even harder to solve, or unsolvable altogether. This is the problem of experience that Chalmers called “the hard problem of consciousness”: Why is it that all the information processing performed by our cognitive systems is joined by an experience? What causes us to have a subjective experience of the color yellow? Why does not all the information processing happen “in the dark” like in the case of (presumably) a microwave oven? Thomas Nagel famously stated that an organism has consciousness “if and only if there is something that it is like to be that organism” (1974, p. 436). Terms like “qualia” and “phenomenal experience” are often used to indicate this property, but regardless of the terminology I subscribe to this definition of consciousness.

The hard problem is so hard because consciousness is irreducible subjective and physicochemical processes do not seem be able to provide a satisfactory explanation of it. This is usually referred to as the “explanatory gap” (Levine, 1983) and it provides a serious challenge to science and monistic interpretations of the mind-body problem, and to the CTM as a consequence. Contrary to this, there are those who argue that there is no such a thing as a problem of irreducibility because what we call experience or subjectivity is no different from physicochemical-induced phenomena such as the capacity to discriminate, categorize and react to stimuli, the integration of information, or the control of behavior (Dennett, 1991). This posture is fully monistic in terms of the mind-body problem and states that once the easy problem of consciousness is solved, there will be nothing else to solve.

While the debate over the legitimacy of the explanatory gap problem continues, science has been moving forward in its attempts to describe the mechanisms by which consciousness operates. In this context, the global workspace (GW) theory of consciousness (Baars, 1997) has been highly influential. According to this theory, the content of consciousness (i.e. what is experienced) is the information produced by specialized unconscious processors that is posted on the GW, which is widely accessible by the entire nervous system. As explained by Baars, consciousness may work as a theater in which there is a stage with a bright spot illuminating some information with
the “spotlight of attention”, thus making it available to unconscious processors spread throughout the dark parts of the theater.

Other theories developed to explain the processes underlying consciousness do not consider it to be widely distributed, as the GW theory does. Such is the case of the framework proposed by Crick and Koch (2003) that argues for localized sets of neural events—the neural correlates of consciousness—being responsible for specifics aspects of conscious percepts. In their model, attention selects between competing stimuli—when overlaps in cortical networks occur—, and as a result it plays a fundamental role in consciousness.

Notice that in both the distributed and localized models of consciousness attention acts as a modulator: at any given moment there is an enormous number of sensory stimuli and internal states that we can potentially experience but do not because attention is not directed at them. Despite this, attention and consciousness appear to exist independently of each other in some occasions. In effect, we can consciously perceive some basic characteristics of unattended objects (Braun & Julesz, 1998; Rock, Linnett, Grant, & Mack, 1992) and, more importantly, information associated with attended objects can be unconsciously processed.

2.3. UNCONSCIOUS PROCESSES

A distinction between conscious and unconscious processes is present in every relevant discipline of psychology and neuroscience: perception, memory, attention, motor control and language production theories all have their own vocabulary for referring to these two types of information processing (see Morsella & Andrew Poehlman, 2013). In this section I briefly review some key theories and concepts regarding these two types of processes.

The unconscious processing of information may refer to either a stimulus, or its influence on behavior and cognition. This distinction is the subject of a debate, as some scholars define “unconscious” as a system that processes subliminal information from the environment, while others understand it as the lack of awareness of the effects triggered by the—often consciously perceived—stimuli (see Bargh & Morsella, 2008). The
discrepancy is not trivial because it determines whether the focus of research and theory is on the input (stimuli perception) or on the output (action control and thought and emotion formation). Bargh and Morsella sustain that the input-oriented approach is not very useful because in nature most stimuli is supraliminal (2008). Video games and other types of media are not a part of nature and thus can be designed to contain substantial subliminal stimuli, but for the purpose of understanding flow states I rely on the second interpretation of the phenomenon (more in Section 3).

To account for the differences between conscious and unconscious information processes, I consider the dual process theory (DPT). According to it, cognitive processes are determined by two distinct systems, usually called System 1 and System 2 (Stanovich & West, 2000). System 1 is widely described as a form of cognition shared by all animals, with rapid, parallel and automatic processes in which only the final product is posted in consciousness (Evans, 2003). Meanwhile, System 2 is thought to be uniquely human, and it presents slow and sequential thinking processes associated with abstract reasoning and hypothetical thinking that are constrained by WM capacity (Evans, 2003; Kahneman, 2011).

As suggested by Kahneman, System 2 is responsible for the subjective experience of agency and choice, and most of the time is only working at a fraction of its capacity, with its main function being to monitor impressions, intuitions, intentions and feelings generated by System 1 (2011). Furthermore, because of its limited capacity, System 2 shows a “reluctance to invest more effort than is strictly necessary” (Kahneman, 2011, p. 31), and its operations are easily disrupted when attention is drawn away. Because of this, System 2 is prone to yield to distractions while—or even after—being cognitively challenged. This phenomenon is known as ego depletion and it implies that volition is a limited resource (Baumeister, Bratslavsky, Muraven, & Tice, 1998).

Similar to the DPT’s System 1 are Koch and Crick’s “zombie systems” (2001). According to the authors, many mammals have online systems (Milner & Goodale, 2006) that process information and corresponding actions in real-time without conscious input, allowing for the execution of complex yet routine tasks automatically, which saves us the hundreds of milliseconds that consciousness takes to set in. The result are zombie-
like states that lack planning, thoughts and explicit memory, and can often be encountered on “highly practiced and ritualized sensorimotor activities that humans love, such as rock-climbing, fencing and dancing” which mastery “requires a surrendering of the conscious mind, allowing the body to take over” (Koch & Crick, 2001, p. 893).

Studies support the idea that perception processes can automatically and unconsciously trigger the activation, modulation and selection of action plans (Morsella & Poehlman, 2013). However, in order to remain unconsciously triggered, actions have to be simple and quickly executed (e.g. button pressing) so that they produce minimal demands on WM (Morsella & Poehlman, 2013) or no demand at all. Regarding this, recent studies have proposed that WM can hold small amounts of information unconsciously, although more evidence is needed to support the claim (Persuh, Larock, & Berger, 2018; Stein, Kaiser, & Hesselmann, 2016).

Whether or not unconscious WM exists, theory backs the existence of unconscious execution of actions triggered by consciously or unconsciously processed stimuli. Thus, flow may be thought as a trance or zombie state in which the individual responds to stimuli without thought or awareness of their actions due to the prevalence of unconscious processes. Despite this, consciousness is necessary for flow since the state is associated with a phenomenal experience, which is linked to the attended supraliminal stimuli. Thus, a complete understanding of consciousness is still necessary for a complete understanding of flow.

As explained, we are everything but certain about the mechanisms of consciousness and its neural correlates. Hence, the model I propose ignores some of these unresolved issues and focuses mostly on explaining the mechanisms by which certain configurations of information processing and attention allow for the emergence of flow’s phenomenology. Considering this, the following section attempts to provide a surface understanding of what attention is and how it works.

2.4. ATTENTION

More than a century ago William James formulated a classical definition of attention that remains popular because of its simplicity and intuitiveness:
Millions of items . . . are present to my senses which never properly enter my experience. Why? Because they have no interest for me. My experience is what I agree to attend to… Everyone knows what attention is. It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects of trains of thought. Focalization, concentration of consciousness, are of its essence. It implies withdrawal from some things in order to deal effectively with others. (1890, pp. 403–404).

As time passed and psychology was progressively taken over by science, definitions had to be updated in order to be cohesive with current theories of the mind in general and of attention in particular. However, it is still useful to analyze some of the key concepts comprehended by James’ definition:

- Competition: several objects contest for the subject’s attention.
- Effectiveness: limited resources produce trade-off scenarios in which some objects must be dismissed in order to “effectively deal with others”.
- Interests: motivation plays an important role in defining which objects are dismissed and which are prioritized.
- Possession by the mind: objects in which attention is focused are the ones experienced (the contents of consciousness); they can be external (accessed through the senses) or internal (states involving thoughts, memories and emotions).

James does not explain the processes underlying the phenomenon, but it does mention some of its components. While some of these were already briefly discussed, this section is focused on producing a deeper analysis based on current theories that accounts for said processes.

We have limited cognitive resources: no animal can process all the information available at any given point in time. Consequently, the selection of information is essential in determining the animal’s behavior—crucial from a Darwinian point of view—and internal states. According to Knudsen (2007), there are four fundamental processes involved in this mechanism that we call (selective) attention: working memory, top-down sensitivity control, competitive selection, and bottom-up salience filters (see Figure 1 for a
visualization of their interactions). The following characterizations of these four processes are drawn from Knudsen’s paper.

**Working memory:**
Holds information for periods of seconds while evaluated. Since it has limited capacity, WM comprises competitive processes that determine what information gains control of the circuitry on the basis of the relative signal strength of associated representations. Information held in WM determines decisions and planning of complex behaviors that, among other things, influences what of all the available information in the environment enters the nervous system (think of eye movements, for example). Furthermore, the contents of WM serve to modulate neural representation signals that impact the results of the competitive selection process. WM appears to be a widely distributed function with areas of the PFC acting as an executive controller, and two separate storage systems known as the phonological loop and the visual sketchpad.

**Top-down sensitivity control:**
A process also known as endogenous attention. It regulates the relative strengths of information signals competing for access to WM. Two mechanisms are used to achieve this: orienting behavior (movements) towards the targeted stimuli (e.g. eye saccades) and modulating the sensitivity of circuits representing information (circuits relevant to target are excited and non-relevant ones are inhibited). As suggested by studies in visual attention, the modulatory effect of top-down bias signals increases with task difficulty and produces shorter response times (both in information processing and decision making).

**Bottom-up salience filters:**
A process also known as exogenous attention by which signals corresponding to certain infrequent or biological important stimuli are strengthened (e.g. a sudden sound or the voice of a parent). As a consequence, information that is likely to be important gains an advantage in the competition for accessing WM even if it is not task-related. Once in WM the information can be evaluated and discarded or kept depending on its importance relevant to other information in the circuitry. If kept, it will serve as the basis for future top-down sensitivity control. Furthermore, unusually strong signals from salient stimuli
may trigger direct top-down control even before accessing WM. This occurs because immediately after a stimulus onset (and for a brief period of time), competitive selection, sensitivity modulation and behavioral responses all work independently, and response time is minimized as a result.

**Competitive selection:**
A process in which information from the environment and internal states (including stored memory) compete to access WM by means of signal strength, which is dependent on the quality of the information (signal to noise ratio), top-down modulations and bottom-up salience filters. Competition occurs at different hierarchies: while at low levels pathways it depends of basic parameters (e.g. spatial location), at higher levels it will occur between neurons involved in more complex representations (e.g. object category). Competitions run parallel for different domains (e.g. visual, somatosensory, etc.) and information is discarded along the way until a final stage to access WM takes place. Studies focused on the visual system suggest that although bottom-up mechanisms can produce saccades towards a distractor, targeted stimuli can regain control of WM within 300 ms. This is important because it shows capacity to stay on task despite of interferences.

![Flow of information and interaction between the components of attention. Based on Knudsen’s chart (2007, p. 59).](image)

**Figure 1:** Flow of information and interaction between the components of attention. Based on Knudsen’s chart (2007, p. 59).

A central property of this model is that the information that takes over WM influences the competitive selection process by modulating neural representations’ signals. This leads to a self-reinforcing dynamic in which winning neural representations tend to preserve control of WM in the future. As pointed by Knudsen this mechanism underlies voluntary
attention (2007). Furthermore, this loop-like circuitry may be what allows for the perpetuation of effortless attention on a particular object: if there is no substantial rivalry or challenge in the processing of a stimuli represented by information that is already in control of WM, then top-down bias signals will provide an advantage to that stimuli in the competitive selection process. This would not only explain events of seamless sustained attentional focus, but also scenarios of inertial attention where the individual appears to be automatically engaged with an object for uninterrupted long periods of time, even when in the larger picture this would be considered undesirable by the individual.

Knudsen’s model falls into the working memory theory ecosystem. Another popular approach used to model attention is the multiple resources theory. As explained by Young and Stanton (2002a), this evolved from Kahneman’s capacity model (1973) that proposed the existence of a single and finite resource pool used by all attentional activities regardless of their nature. This would mean that if demand for resources is high then the pool is drained and two different tasks, no matter how different, will interfere with each other. However, later experiments suggested that different tasks could be perfectly time-shared independently of their difficulty level (i.e. of demanded resources) (Wickens, 1991), leading to the development of a multiple resource theory that argues for pools of resources along three dimensions: processing stage (early or late), input modality (visual or auditory) and type of processing (verbal or spatial).

Even though these theories have not been conciliated, they present overlaps and may even be compatible (Young & Stanton, 2002a). In fact, elements from both theories have been combined to explain the Yerkes-Dodson law, which states that the relationship between arousal and performance takes the form of an inverted-U curve (Yerkes & Dodson, 1908). According to Young and Stanton, variations in arousal are positively related to attentional resources but negatively related to WM capacity, creating an optimal point of arousal (2002a). This negative relation could be due to high levels of arousal creating tunnel-vision scenarios in which the objects of attention are highly narrowed, thus requiring more WM capacity to inhibit irrelevant stimuli.
Applied research usually considers attention capacity to be fixed in the short term (Young & Stanton, 2002b). However, besides arousal (Kahneman, 1973), mood and age—which is irrelevant for the short term–have also been proposed to affect attention capacity (Hasher & Zacks, 1979). Furthermore, mental work load may also have a direct impact on attention capacity: the Malleable Attentional Resources Theory (MART; Young & Stanton, 2002b) states that when confronted with mental underload, the size of the relevant resource pool diminishes. This could explain why decreases in demand do not necessarily lead to increases in performance, and why low task difficulty can result in poor performances (since resource pool size does not instantly adapt to mental workload fluctuations).

The theories previously described allow for divided attention to occur. The capacity model argues that, although there will be interference between tasks regardless of their nature, resources can be distributed in a simultaneous fashion. The multiple resource and WM theories argue for the existence of independent processing pathways–and resources/capacity–depending on the task modality, so not only attention can be divided but also certain processes can be performed simultaneously without detriment. In fact, there are experiments that support the latter and even provide evidence of cross-model facilitation in which certain auditory stimuli decreases the response time to certain visual stimuli and vice-versa (Alais, Morrone, & Burr, 2006). However, the literature is not unequivocal regarding divided attention. Central bottleneck theories developed after Broadbent’s filter model (1958) sustain that attention involves central operations that do not allow for simultaneous processing and argue that the phenomenon known as “psychological refractory period” observed in experiments supports this (Ruthruff, Pashler, & Klaassen, 2001).

The divisibility issue sparks many questions: What are considered two different objects of attention? Is a song with multiple instruments and being broadcasted asymmetrically through a stereo system a single object or multiple ones? Is a piano playing several notes at the same time a single object? What is an “object-of-attention unit”? Regardless of these questions (I do not intend to answer them), there is something certain: attention can be directed towards different types of stimuli. Although it was not mentioned, most of the theory reviewed so far is focused on explaining how attention to external
(sensory) stimuli works. In particular, a great deal of the implementations and experiments pertain visual attention. However, understanding the mechanisms of attention towards internal states is crucial to elaborate a comprehensive model of flow. In this light, the following section consists of a review on inwards attention.

2.4.1 INWARDS ATTENTION

In terms of William James’ definition, inwards attention occurs when internal states—as opposed to sensory stimuli—take possession of the mind. Across the literature there is a common distinction between two types of inwards attention: task-related (TR) and task-unrelated (TU). This distinction is useful for classifying behaviors in experiments on performance, but it does not contribute to explaining the phenomenon’s essence, as I argue later in this section. In fact, my thesis on the mechanisms underlying flow partially relies on this distinction being a pragmatic one (i.e. there is no fundamental correlation with brain processes). However, analyzing the dichotomy can still provide valuable insight for the study of flow.

TR activities can involve a series of inwards-oriented phenomena required to complete the task at hand, like autobiographical memory recall (Williams & Scott, 1988), mental imagery (Shepard & Metzler, 1971), deductive reasoning (Johnson-Laird, 1999) or metacognitive representations. Notice that the same phenomena often occur in TU inwards attention scenarios, which may facilitate the transition from TR to TU attention that cancels flow. To better understand how this transition works, I provide a review on TU inwards attention, also known as mind wandering. Keep in mind that the TR-TU distinction will lose part of its relevance though.

The term mind wandering may evoke the idea of an unspecific process where attention hops randomly from one mind object to the next, but as this section suggest, there is nothing “random” about it. Mind wandering is ubiquitous in our lives (Killingsworth & Gilbert, 2010). This is probably caused by the existence of alternative goals that become the object of mental simulations useful to reduce risk (Cleeremans & Jiménez, 2002; Dehaene & Naccache, 2001) and to solve complex problems requiring long periods of computation (Binder et al., 1999). Because these processes help us plan crucial future behavior our cognitive system needs to be sensitive to opportunities that facilitate goal
completion, which is why mind wandering is often automatically triggered by salient stimuli (Gollwitzer, 1999). Said differently, we are continuously processing information about the past and present in order to optimize future performance by automatically thinking of solutions to a variety of current and potential future problems.

Smallwood and Schooler propose that salient stimuli relevant to alternative goals can trigger executive control to switch attention towards TU internal states, similar to the way eyes saccades switch attention direction towards salient visual stimuli (2006). In effect, individuals exposed to dichotic listening tend to direct their attention more towards the channel with self-relevant (Bargh, 1982) and goal-relevant (Gollwitzer, 1996) information. Furthermore, after directing attention to a channel with stimuli related to a personal concern, individuals increase the number of thoughts related to that concern (Klinger, 1978). In this context, research suggests that high degrees of concerns (e.g. dysphoria) are associated with higher frequencies of mind wandering (Smallwood et al., 2003).

Recognizing the multiplicity of goals\(^1\) puts the TR/TU dichotomy into perspective: it is not that when attention is directed towards a TU activity the individual is “distracted” with something random or unimportant: TU attention—whether external or internal—is goal-oriented, the same way TR attention is.

Another relevant distinction is Giambra’s classification of mind wandering episodes into “spontaneous” and “deliberate” (1993). These two categories describe the intentionality underlying executive control’s switching of attention. Because of this, the classification may be mapped to the type of signal modulation triggering this switch. In effect, I argue that those episodes classified as spontaneous are predominantly triggered by bottom-up saliency, while those classified as deliberate are predominantly triggered by top-down modulation mechanisms. Because of this, spontaneous attention involves less self-reinforcing dynamics and as a result is characterized by the “jumps” between stimuli that are so typical of mind wandering. Meanwhile, deliberate TU attention is more focused,

\(^1\) Across the literature terms such as “self-relevant” and “personal concern” are used. I consider these terms to fall into the broad category of “goals”, for if something is not personally relevant or is not of concern then it would not be a goal.
similar to TR attention. The difference between these last two then relies on a somewhat arbitrary categorization of the activity, as both TU and TR attention are goal-driven.

All things considered, I reserve the term mind wandering to refer to inwards attention that is mostly reflexively (bottom-up) driven by information–sensorial or internal state–associated with the person’s goals (e.g. someone sees a credit card on the screen and remembers that they still did not pay the credit card bill, which reminds them of the bill of rights assignment they do not want to do for next class, which leads to them thinking about winter break, and so on). Meanwhile, deliberate inwards TU attention is understood as a predominantly top-down modulation process that tends to be focused as a result of self-reinforcing dynamics (e.g. they see the credit card on the screen, remembers that still did not pay, and proceeds to think of a plan to do so).

Throughout Section 2 I reviewed theories and evidence on consciousness, self-awareness, unconscious processes and attention that I use as foundation for the proposed interpretation of flow. Now that the pieces are all set, it is time to put them together.

3. A MODEL FOR FLOW

In this section I present the “conditions” for flow, which are hypotheses about the core cognitive processes necessary for the phenomenal experience to occur. These conditions are followed by a description of interrelated mechanisms that help to fulfill them. Throughout the section I rely mainly on the WM framework to depict attention, and on the DPT to account for unconscious processing of information. A recap of the model–plus the heuristics derived from it–can be seen on Figure 9.

3.1. CONDITIONS FOR FLOW

1. Exclusive Attention on Sensory Stimuli (on what information is processed)

WM is fully and uninterruptedly controlled by information corresponding to the flow-activity stimuli. For this, TR signals strength must be higher than any other, so they perpetually win the competitive selection process to access WM. This is achieved through a combination of high information quality, bottom-up saliency and top-down modulation processes that ensures that TU signals are either repressed before reaching
WM or discarded immediately (300 ms) after they do, so the interruption is not perceived (Knudsen, 2007).

2. Conscious Input, Unconscious Output (on how information is processed)
While sensory stimuli are consciously processed and gain access to WM, actions triggered by these stimuli are executed unconsciously and associated information bypasses WM. This means that no planning, thoughts or explicit memory of intermediate steps leading to outputs exist. In a fashion similar to the rapid decisions described by the recognition-primed decision (RPD) model (Klein, 1993), there is no comparison of alternatives: the recognition of patterns triggers a procedural execution of an already existent action plan, allowing for reflective top-speed and high-performance. For this to happen, skills must be sufficiently high in relation to three types of complexity—of sensory stimuli, action execution, and system navigation—.

3.2. FULLFILMENT OF CONDITIONS

Catching Retaining and Avoiding Intrusions
To win the competition towards WM and retain control over it, sensory information must leverage three variables.

Information Quality
Poor sensory information quality should only be allowed when it is part of the proposed challenge: decoding information should be as easy as possible except when the nature of the activity itself requires it not to be (this translates to a clear graphical user interface, for example).

Bottom-up Saliency
Optimal sensory stimuli includes conspicuous elements that leverage saliency maps and as a result gain almost instant (25 to 50 ms) access to WM regardless of the nature of the task being performed (Itti & Koch, 2001; Knudsen, 2007). These salient stimuli should

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2 Notice that although individuals are not conscious of the actions triggered by the sensory stimuli, they can be conscious of the sensory stimuli triggered by the actions (e.g. pressure on a fingertip as a result of button pressing).
not be related to personally relevant goals or concerns (so mind-wandering is avoided) and, ideally, are used to re-grab attention after TU information accesses WM.

Top-down Modulation

During flow, top-down modulation processes constantly excite TR sensory stimuli signals and inhibit all the rest, including those from TR thoughts and plans. Because WM is exclusively controlled by sensory stimuli information, individuals act without considering any goals, including those proposed by the activity (an automatically-executed pre-existing plan already contemplates them). I call this phenomenon *temporal horizon blindness*, and it implies that no matter how pressing other goals might be, they will be neglected for as long as flow is uninterrupted.

Mechanisms involved in signal modulation are also self-reinforcing (Knudsen, 2007), which means that winning neural representations tend to preserve WM control. This leads to inertial attention in which something (a salient stimuli) must actively break the loop for flow to cease.

In conclusion, leveraging top-down modulation processes requires sensory stimuli to not trigger interruptions. This relies on the appropriate behavior of the “information quality” and “bottom-up saliency” variables, as well as on the compliance with the optimal complexity conditions from the following section.

Optimal Complexity

Activities have an *optimal complexity level* (OCL)—in three interrelated categories and always relative to the individual’s skills—that help keep attention exclusively on the sensory stimuli and that allow for the procedural execution that keeps System 2 at bay. An OCL considers not only the real complexity level, but also the perceived one to prevent the individual from making an object of attention out of the complexity itself.

*Type 1: Sensory stimuli complexity*

Challenges effectivity and efficiency of sensory-related information processing. Depends on the individual’s skills to achieve a high necessary-to-unnecessary (for achievement of goal) ratio of information processing.
The OCL is sufficiently high, so all WM capacity can be filled by TR sensory information, leaving no idle capacity that could be filled by TU information. Likewise, complexity is sufficiently low to avoid an overflow of WM that leads to repeated failure, which can itself become an object of attention in the context of frustration, and which usually comes together with interruptions (e.g. loading screens in video games).

Notice that individuals can potentially compensate for low sensory stimuli complexity by increasing their observational depth-level, thus remaining fully absorbed by the activity’s stimuli. This means that a minimum complexity level is not required for flow, although it certainly facilitates it by giving no choice to the individual but to fully attend the activity. As an example, think of video game’s “zen modes” in which sensory stimuli complexity is low due to its irrelevance for achieving goals (it is usually impossible to lose in these modes): players can be fully attentive of the sensory stimuli, but they can also have their attention divided without detriment.

Sensory stimuli can also appear to be impossibly complex, but if all that is needed to achieve the goal is a scan of the most superficial layers of information, then WM capacity can suffice. As an example, think of a first-person shooting game (FPS) with hyper-realistic audiovisuals: there is a myriad of elements the player can pay attention too, but most of the game only requires recognizing shapes and movements to identify targets.

*Type 2: Action execution complexity*

Challenges effectivity and efficiency to execute action commands, such as motor commands. Depends on the individual’s skills to flawlessly perform a high necessary-to-unnecessary ratio of action commands.

The OCL is sufficiently low, so that action commands can be executed procedurally (only System 1/zombie systems are engaged), bypassing WM (there is no conscious input) and thus producing faster response times and freeing storage for sensory stimuli processing. Potentially, the OCL can increase up to the point where the individual is not physically capable of executing a command. This is the case of professional NES Tetris (Nintendo, 1989) players that cannot physically cope with the speed of level 29 (also known as the *kill screen*).
Type 3: System complexity

Challenges skill to navigate the activity’s system, which requires identification of necessary/unnecessary stimuli to process and actions to execute for achievement of goals (notice connection with the two other skill types). This skill is a result of a combination between (1) knowledge of the system and (2) deduction power.

The OCL demands minimal deduction power, so a plan based on a mental map of the system generated throughout previous experiences is procedurally executed. If this was not the case and active mental representations were necessary, then a portion of WM capacity would be allocated to internal states, leading to a phenomenon known as perceptual decoupling in which the processing of sensory stimuli information is handicapped (Schooler et al., 2011). In other words, the individual must be able to recognize patterns and react to them without engaging in analytical decision making involving conscious awareness of the intermediate steps leading to action execution.

4. VIDEO GAME DESIGN HEURISTICS FOR FLOW

From the model outlined in the previous section, I derive a set of design heuristics for video games that intend to elicit flow states. While the first three aim to help fulfill Condition 1 (the “what”), the following three are focused on Condition 2 (the “how”). Keep in mind, however, that because conditions intersect these relationships are not linear.

4.1. MINIMIZE TIME BETWEEN ACTIONS

Giving players time to make evaluations of the past and projections about the future can lead to them generating mental representations, planning, retrieving memories from previous attempts, and evoking self-related contents as consequence of thoughts about success and failure.

A game can provide a myriad of choices to make but if the player is forced to act intuitively and is given no pause, then WM can remain controlled by sensory stimuli and procedural action execution may not be interrupted. As an example, think of a FPS
game: non-discrete choices could lead to endless evaluations of optimal strategies, but because the rhythm is so fast-paced, action just flows. Because during delays in action production we evoke action-related imagery into consciousness (Morsella & Poehlman, 2013), waiting time before actions needs to be minimized. This is why turned-based games are generally not well suited for flow, except when turns are virtually non-existent. Take “bullet” chess for example: compared to the standard 90-plus minutes that each player has in a typical FIDE match, in bullet matches this time is reduced to less than 3 minutes. The difference, which can be seen in recorded footage, is that while in both versions players are extremely focused, only in the latter their behavior is aligned with RPD models where attention is not directed towards internal states.

Time between actions must also be minimized to discourage assessments about past events. This is particularly important after failures, meaning that time before play is re-started should tend to be null. To deal with this, games with significant loading times may provide waiting tasks to players (e.g. a mini game or, in multiplayer games, a spectator camera).

This heuristic does not modify a game’s real complexity, but forces players to ignore a portion of it and thus modifies their perception. As a result, it can help players meet their OCLs when otherwise complexity levels would be too high. Notice that this heuristic is related to the traditional flow prerequisite of direct and immediate feedback (Table’s 1 element No. 8), although is not quite the same: its focus is on the players and how they allocate their cognitive resources since the intent is to keep players reacting to the activity regardless of how this one reacts to them.

4.2. DESIGN FOR THE ZOMBIE WITHIN

A less self-relatable game means lower chances of salient stimuli triggering interrupting thoughts. This is achieved by leveraging the game’s aesthetic, mechanics and theme/plot. Specifically, audiovisuals should tend to be abstract and, more importantly, tasks should be mechanical and theme/plot non-existent or difficult to relate to.
As discussed, the sense of self-awareness is the result of an active mental representation that requires attention to be at least partially directed inwards. Therefore, activities that intend to elicit flow must not require self-associated processes such as theory of mind or moral decisions. Because of this, video games in which the player interacts with complex characters emulating human behavior or with narratives dealing with human values will not be “flow-friendly”.

![Diagram](image)

**Figure 2**: Four video games are placed on a spectrum according to their hypothesized capacity to elicit flow. To do this, I classified their mechanics, plot and aesthetics into two categories: “zombie-appealing” and “self-relatable”. These criteria suggest that NES Tetris (Nintendo, 1989) is the most flow-friendly game, followed by Counter-strike: Global offensive (Hidden Path Entertainment & Valve Corporation, 2012), Thomas was alone (Bithell, 2012), and Life is strange (Dontnod Entertainment, 2015) coming in last.

Although they entail a higher risk of displaying personally-relevant salient stimuli, narratives may not interrupt flow. In this context, cutscenes are best because they do not explicitly ask players to assess intentions or make value-based decisions that would
require System 2 engagement. This being said, flow is facilitated when games appeal to the zombie that lives in all of us by exclusively requiring sensorimotor tasks and offering abstract content (see Figure 2 for a classification example). Regarding this last bit, visual objects should have no apparent real-life function, so self-related actions are less likely to be evoked into consciousness. For example, a person that sees a pizza may perceived it as something they could eat but is less probable to consider something similar with a yellow pentagon.

### 4.3. LEVERAGE SOUND DESIGN

The exposed theory in which WM has two separate storage systems for visual and sound-related information (Knudsen, 2007) implies that these do not compete for control of WM capacity. Thus, activities that aim to elicit flow should leverage both categories. Since the other heuristics are more focused on the visual side of the equation, this one deals with sound.

Understandably, sound design is frequently a lower-priority area compared to visual design, but if designers want to maximize the chances of eliciting flow they should be thoughtful of what players are going to listen to while playing their game. To begin with, players should listen to something most of the time as this contributes to precluding TU sounds from either accessing WM or from being heard altogether. Even when audio is not part of the game’s challenge, as with visuals it needs to meet the OCL: not too high so the complexity does not become an object of attention and not too low to facilitate the filling of WM capacity (of the phonological loop in this case).

To avoid evoking TU thoughts audio should be difficult to relate to, which means that verbal content (e.g. music’s lyrics) should be discouraged (see heuristic No. 2). Moreover, to help attention being kept on the sensory stimuli and to facilitate procedural execution, audio patterns should be synchronized with visual stimuli and action execution patterns (note that these depend largely on the system’s patterns). The hypothesis behind this is that inertial attention is more likely to be interrupted by metacognitive or evaluation processes when patterns are more difficult to recognize (see heuristic No. 6) and when different patterns are not synced (so cross-model facilitation is handicapped). Thus, flow-friendly games should exhibit relatively simple and unified sensory and action
execution patterns, which in particular means that sound will tend to present a consistent beat and repetitive notes. A good example of this are rhythmic games where the action execution patterns are often matched by visual and audio patterns (see Figures 3 and 4 for examples).

Figure 3 (left) & Figure 4 (right): In Super Hexagon (Cavanagh, 2012; left) audio and visuals patterns are synchronized, while in Crypt of the NecroDancer (Brace Yourself Games, 2015; right) audio is also in sync with action execution requirements. My hypothesis is that these dynamics help to preserve inertial attention, as patterns are easier to recognize and cross-model facilitation contribute to procedural action execution that precludes TU thoughts.

4.4. PLAYERS MUST MEET THEIR OCLS

Skills vary between players, as well as within players throughout a playing session (due to cognitive and/or physical depletion). Consequently, players must meet their OCL in each of the three domains, at all times. This can be achieved by embedding the game with either (1) multiple levels of complexity—in the form of coexistent layers or in separate sections—that the players can pick from (example in Figure 5) or (2) a dynamic adjustment system (Hunicke, 2005) that picks the right complexity for the player.

One way to attain (1) is to offer multiple goals for each section or level of the game: while an easy goal (e.g. “reach the end of the level”) entails just a few objects to scan, simple button combinations to press and does not require elaborate mental maps, a second more complex goal that can be independent or not from the easy one (e.g. “collect all gems” or “finish the level in less than 90 seconds”) would crank up all complexity levels. Likewise, (2)—and (1) too—can be attained by keeping an immutable goal (e.g. “win the race”) while modifying the conditions in which the action takes place (e.g. rivals’ speed varies and obstacles change places).
As mentioned, OCLs contemplate the player’s perception of complexity. In this sense, this heuristic has its similarities with the traditional flow prerequisite of skills and perceived difficulty being balanced (Table’s 1 element No. 9). However, the OCL concept is more precise and thus may be more actionable.

4.5. OPTIMIZE COMPLEXITY NOT DIFFICULTY

Complexity and difficulty sometimes move in the same direction, but they are not the same. When the benefit provided by added features producing extra complexity is higher than the cost of the extra cognitive load, challenges are easier to beat but both Condition 1 and Condition 2 for flow are more elusive.

As an example—see Figure 6 for a visualization—think of versions of Tetris (Nintendo, 1989) that allow players to hold a piece for future use: this feature can be life-saving, but at the same time it adds complexity to the system (and to players’ mental map of it), to the execution of commands (there is one more button to press), and to the visual interface (the piece on hold is displayed on the screen), which means that more skills are needed for flow to emerge.

Someone could argue that players can just choose to not use added features like the ones exemplified. While this is a possibility, the sole presence of these features may still contribute to modifying players’ perception of the game’s complexity levels. In the case of Tetris, for example, the presence of an extended “next” section queue may trigger anxious thoughts about unmet demands, even when the player is not using this information to their advantage.
A game can also have the exact difficulty level to keep the player engaged, but if OCLs are not met then flow will not occur. This is what usually occurs with chess, whose system is complex enough to preclude procedural execution from being a constant even in expert players. That said, this type of high-complexity scenarios can still be optimized for flow by implementing the advice from heuristic No. 1.

4.6. FACILITATE LEARNING WITH PREDICTABLE SYSTEMS

As explained, individuals need to be able to procedurally navigate the activity’s system, which means that they must know—not deduct—its possible states and their respective contingencies well enough. This learning process is facilitated when the system is predictable (i.e. when it is composed of easily recognizable patterns). This does not imply that at any given point a player should be able to predict the game’s future states. Rather, it means that they should not be surprised by any of these states because they lie within parameters clearly defined by the rules.

Some video games, especially those that have narrative elements, are designed to be unpredictable; they intend to surprise. The “problem” with this is that players are encouraged not only to evaluate circumstances, but also to make an object of attention out of the surprise itself. Unexpected events push us to revise and update a narrative of our own that we use to explain reality. Contrary to this, games with predictable systems do not defy expectations: after building the corresponding mental model we can play non-stop without consulting with ourselves about the events that transpire.
The less contingencies are involved, the easier it is to learn the system and build a mental model of it that can then be automatically executed. Thus, to build simple enough systems, choices should have low and/or short-term interdependency. Games that comply with this and that have easily recognizable rules (i.e., patterns) allow players to meet their system OCL easier (see Figures 7 and 8 for examples).

Meeting the system OCL facilitates continuous play without invoking System 2. Consider once more the case of NES Tetris: expert players know the system so well that they can play until task complexity reaches their sensorimotor skills limit (tapping speed, mostly). This does not happen in many other games, as their systems are more complex and thus the limiting variable is decision making instead of physical capacity.

A traditional flow prerequisite is to embed the activity with clear goals (Table’s 1 element No. 7). As I argued, goals are irrelevant during flow states. What matters is that the system must be composed by clear and simple enough patterns that the individual can recognize and react to. In this context, the game’s rules, visuals, and even its sound (see heuristic No. 3) should not aim to surprise.

This section focused on making the hypothesized flow model actionable for the purpose of designing games (as mentioned, a diagram summarizing my propositions can be seen
in Figure 9). The following section discusses the implications of the model for the understanding of flow’s phenomenology—today based mostly on Csikszentmihalyi’s work—, and for identifying flow’s place relative to other pertinent concepts.

5. DISCUSSION

The purpose of this work is to produce a scientifically robust theoretical framework that helps to understand the cognitive mechanisms underlying flow states. However, the presented model needs to be operationalized to be tested. This should be the task of future works that concentrate on hypothesizing about the neural correlates of the phenomenon. Until this is done, and the pertinent tests performed, not much can be said about the limitations or the validity of the proposed framework and design heuristics. Having said this, the one discussion that can be had concerns what the model has to say about flow’s phenomenology: if my framework were to be considered axiomatic, what conclusions could be drawn from it?

In this section I apply learnings from the model to discuss and revise the traditional characterization of the phenomenon. While I agree with the presence of Table’s 1 elements No. 1 to 4 during flow experiences, I sustain that ultimately the phenomenology can be described solely by element No. 1 (although modified).
Meanwhile, I argue that elements No. 2, 3 and 4 are specific instances or conditions of element No. 1, and that elements No. 5 and 6 are not part of the phenomenology. What follows is a review of these claims and related topics.

**No. 1: Merging of Action and Awareness**

I believe the title given to this phenomenological element lends itself to confusion, as the word “action” does not refer to the execution of commands, but to the activity-related events. In effect, Csikszentmihalyi explains that during flow awareness merges not only with actions but also with the objects that those actions are directed towards: “A tennis player pays undivided attention to the ball and the opponent”, he exemplifies (2014, p. 138). In this sense, my model supports Csikszentmihalyi’s observation in spirit, as I suggest that during flow individuals’ consciousness is filled exclusively by sensory stimuli associated with the activity in question (the ball’s shape and color or the arm’s vibration that results from hitting the ball, for example). This is because all intermediate steps leading to actions are unconsciously processed, with WM being accessed only by TR sensory signals. As a result, there is no place for intermediate thoughts interpreting the stimuli (i.e. abstractions), and there is a merging of consciousness and raw sensory stimuli.

I draw two propositions from the previous paragraph. The first one is that “merging of consciousness and raw sensory stimuli” would be a more precise title than the current one. The second is that the following three elements of the traditional characterization are instances or conditions of this element. Being conscious of something is having a phenomenal experience of it. Thus, if flow is characterized by the merging of consciousness and sensory stimuli, then the state cannot be associated with experiencing a self (element No. 2) or the passage of time (element No. 4), since these would involve the intrusion of extra-sensorial objects into consciousness–Csikszentmihalyi has already noted this (2014), although he did not have a robust theoretical framework to support his observation–. Furthermore, I pose that the “intense focus on the present moment” (element No. 3) is not part of the phenomenology, but a condition for it (similar in spirit to my model’s first condition, in fact). This is because attention itself is not something that can be experienced, but something that determines what is experienced.
No. 2: Loss of Self-Awareness

As explained, the self is nothing more than a representational content that is evoked into consciousness as a result of metacognitive processes (e.g. recognizing that a sensory stimulus, an emotion, or a thought has arisen in consciousness). My model suggests that this is incompatible with flow, thus leaving self-awareness and other associated processes (e.g. theory of mind, planning) out of the equation.

The self is a major component of the narrative that each of us creates to make sense out of reality. This is partly why flow states throw us back to a primal state; to the zombie that still lives in each of us. Someone may think that the term “zombie”–used by Koch and Crick to refer to online systems that execute simple sensorimotor actions–is used in this paper in a derogatory way, but this is not the case. While it is true that the zombie is incapable of abstraction, this is the very reason that makes it so much better at executing mechanical tasks and at being in the present moment. Its actions are not supervised by schemas, making it faster and more implacable, and its emotions are not restricted by thoughts, making it better at connecting with its surroundings. The zombie does not judge or discriminate, and thus can make an object of deep contemplation out of the most trivial of things.

The loss of self-awareness may also be part of what makes flow states so powerful and compelling, as the absence of a self that is used as a reference point for all evaluations may translate into experiences feeling objectively “true” (as opposed to subjectively “true”).

No. 3 & No. 4: Intense Focus on the Present & Distortion of Temporal Experience

Each of the first four elements are ultimately describing the same thing, as I argued. In the case of these two, their names make it evident.

In my model, “intense focus on the present moment” translates to Condition 1 where WM is exclusively controlled by sensory stimuli information, thus producing a temporal horizon blindness where concepts related to past or future times, such as goals, are not posted in consciousness. An ongoing procedural execution allows individuals experiencing flow to act without evaluating past events or future projections. As a result, with no past or future, there are no reference points in time that can be used to measure the pass of
it. Flow is being always in the now: it is the sum of infinite points with no length, and thus feels like infinity and an instant at the same time.

**No. 5: Experience the Activity as Autotelic**

An activity is autotelic when it is intrinsically rewarding, having a purpose in itself. While it is true that activities eliciting flow are autotelic in the sense that they do not need to provide an extrinsic motivation to generate engagement, this is a property of the activity and not of the experience.

I think that the word autotelic is not appropriate to describe the phenomenology since during flow the very concept of purpose is meaningless due to the reactive nature of the state. What is more, because of the inertial attention underlying it one cannot say that the state is an election, so describing individuals under flow as “motivated” would also be incorrect. As a result, I think Csikszentmihalyi made a mistake when he wrote that “flow is experienced as autotelic” (2014, p. 146).

A somewhat tangential observation is that my model predicts that the more extrinsic motivators an activity has, the less flow-friendly it will be since it will present more opportunities for individuals to allocate WM capacity to internal states. Potentially, this observation could derive into a new heuristic for video game design recommending the absence of rewards and punishments that are not part of the game’s core mechanic (e.g. badges).

**No. 6: Sense of Control or Agency**

The sense of agency stems from the perception that one causes their own actions; that there is a correspondence between intention and outcome (Morsella & Poehlman, 2013). As a result, the sense of agency must be joined by a sense of self-awareness. In the words of Thomas Metzinger (2018):

(...) But since the real cause–unconscious, sub-personal processes, such as synapses firing–can’t be represented within the workspace of our consciousness, the brain tells itself something else: there must be a *self* acting so as to make all these thoughts and actions occur! The conscious experience of volition and agency are simple and elegant inferences to the best explanation.
It follows then that flow’s phenomenology cannot include a sense of control or agency and that this is only perceived through introspection a posteriori. This is backed by evidence suggesting that the sense of agency is an aspect of conscious action control (Morsella & Poehlman, 2013) and a result of DPT’s System 2 involvement (Kahneman, 2011), both of which I hypothesize to be absent in flow.

Csikszentmihalyi (2014) decided to include the “sense of control” as part of the characterization of flow, despite recognizing that it can only be felt after the experience. This, I believe, created an unnecessary confusion. In his words:

Rather than an active awareness of mastery, it is more a condition of not being worried by the possibility of lack of control. But later, in thinking back on the experience, a person will usually feel that for the duration of the flow episode his skills were adequate to meeting environmental demands, and this reflection might become an important component of a positive self-concept. (p. 142).

Notice that for the same reason that the sense of agency can only occur a posteriori, someone cannot “realize” that they are experiencing flow, as evoking this concept into consciousness would be enough to interrupt the state. Thus, as Koch and Crick remark, one can only become aware of these type of experiences in retrospect (2001).

6. CONCLUSIONS

Historically, flow research has taken an outside-in approach: field observations and self-reports are used to describe and explain the state, and then efforts are directed to figuring out how to replicate the observed phenomenology. This is particularly true across the video game literature and industry, where oftentimes Csikszentmihalyi’s work is considered a guide. In this work I took an inside-out approach: through my model, I first hypothesized about the processes underlying flow states, and based on this I produced a set of video game design heuristics to elicit them.

The model is an attempt to rethink flow on the grounds of cognitive science theory by putting the processing of information at its core. As such, this work can help explain the roots of some of the phenomenology depicted by the traditional characterization (in Table
1). In this regard, I pose that flow experiences can be described solely by the “merging of consciousness and raw sensory stimuli”—a reformulation of the original “merging of action and awareness”—, which is the result of individuals’ working memory being accessed exclusively by sensory signals associated with the activity (Flow’s Condition 1), and intermediate steps leading to actions being unconsciously processed (Flow’s Condition 2). Meanwhile, I consider the loss of self-awareness and the distortion of temporal experience to be instances of the merging of consciousness and raw sensory stimuli, since the latter means that representational models of the self and of time are not evoked.

The model also rejects some of the phenomenological elements present in Table 1. In effect, it suggests that the sense of control or agency is not a part of the flow experience, but something that is only perceived through introspection a posteriori; that the activity is not experienced as autotelic since the very concept of purpose is meaningless due to the reactive nature of the state; and that the “intense focus on the present moment” is similar to my model’s Condition 1, and not part of the phenomenology.

As argued, some of the design heuristics I propose bear similarities with traditional ones but may be more actionable due to their higher precision or different focus. Other heuristics, such as No. 2 (“Design for the Zombie Within”), are novel and specifically created for video game design. Thus, this paper might provide added value not only to the academy but also to the industry.

This work also aims to better define what flow encompasses. As an example, the term has been used by Csikszentmihalyi to describe professional regular-chess players’ experiences (2014). This is not endorsed by my framework: as explained in heuristic No. 1, regular chess can stimulate deep concentration, but only hyper-fast versions of the game are well-suited for fulfillment of the two hypothesized flow conditions.

All the theoretical work hereby exposed ought to be further developed and tested. For this, it will be necessary to pinpoint candidates for neural correlates with the purpose of applying brain scanning techniques to test if the experiencing of flow (assessed through self-reports) matches the model’s predictions at a neural level. In this regard, future work
should include an extensive literature review on previous attempts to operationalize flow. Furthermore, design heuristics must be tested in controlled experiments to verify if indeed they are useful to encourage flow in video games.

Video games are played on the mind, not on the screen. This is why my work can potentially have ramifications that exceed the field of game design and why my model may be applied to other domains such as mindfulness meditation, psychotherapy, education, work and music. To conclude, if nothing else, I hope that these pages provide readers some insight into the workings of the mind so that they can have a healthier and more meaningful relationship with both the world outside and within.

REFERENCES


