Chapter 2
How and Why Our Mind Wanders?

Guillaume Pepin and Alex Lafont

Introduction

What is “to think?” One book will not be enough to grasp what is thinking in its tremendous complexity. “To think” means considering, evaluating. For some, without thinking the world would not really exist. Plato defined thinking as “the internal speech that soul silently has with itself.” Thinking might therefore be compared to an ability, proceeding outside human consciousness allowing him to consider situations to reach satisfactory decisions.

What is “wandering?” It is the action carried out by the wanderer which is unpredictable and in a constant evolution. In its “metaphysical meditations,” the French philosopher René Descartes said: “My mind is a wanderer which enjoyed to lose itself and suffer from being stuck inside the limits of truth.” In its innocent definition, the wandering thought would therefore be pleasant and contrast to a limited, suffering maker reality. Descartes saw the mind as an entity with a full part existence and a proper willingness, able to disconnect from the outside reality.

Mind-wandering (MW) is therefore a state in which our thoughts are in a constant and unpredictable motion. It is an ability of our mind to switch from external to internal focus allowing us to temporarily free from the boundaries of the outside world. However, during MW, reading comprehension is impaired (Schooler, 2004; Was et al., 2019), and performances tend to drop down during a whole set of tasks (Smallwood & Schooler, 2006; Smallwood & O’Connor, 2011). Therefore, what is the point of these moments? What does it cost us and why is this sometimes beneficial to temporarily escape from the outside world? Additionally, why is this so difficult to prevent the wandering of our mind? To provide the beginnings of an answer

G. Pepin (✉)
University of Lyon, Lyon, France

A. Lafont
Institut Supérieur de l’Aéronautique et de l’Espace (ISAE), Toulouse, France

N. Dario, L. Tateo (eds.), *New Perspectives on Mind-Wandering*,
https://doi.org/10.1007/978-3-031-06955-0_2

to these questions, it is important to understand the concept of attention. In the next part, we will introduce different definitions and models of what is human attention.

Models of Attention

Attention is an ability of animals allowing them to prioritize or organize the research of information. Our attention guides us in a whole set of daily activities allowing us to dynamically interact with our environment. Because attention is not a simple concept, many studies have tried to explain how attention operates. Different theoretical models have therefore tried to conceptualize mechanisms underpinning the experimental results obtained in these studies and presented in the scientific literature over the years. In the 1960s, first researchers who studied this topic thought that attention might have a filtering function.

Is Attention a Filter?

Historically, part of the earliest models of attention sought to explain this phenomenon by imagining attention as an early sensory filter of information processing (Broadbent, 1958). A stimulus (e.g., sound) that is not of primary interest would be filtered to allow better processing of the relevant information. The processing would therefore be dedicated to the expected information. But the "cocktail party" effect moderates this binary vision. Let's imagine a mundane situation in which many people are in a room and chatting with each other. If we are focused on what a person at the other end of the room is saying, it is likely that we will process the words and thus understand the content of the speech rather than those from another discussion at the other end of the room. However, if one of the people in the crowd pronounces our first or last name, this particular word should, according to the Broadbent's model, be filtered, which will not be the case here. We were listening to our partner and focused on the discussion and not to our name that suddenly popped. Yet, we managed to hear precisely that element. This illustrates that the processed information are not always the expected ones, but those which are relevant to the individual. The processing of relevant stimuli is therefore not compatible with the model of Broadbent (1958). Several updates to this model have been proposed to respond to this problem by suggesting a later sensory filter. Treisman's (1969) model postulates that unexpected information is not completely filtered, but rather attenuated.

Is Attention a Pool?

According to Kahneman's model, the performance obtained following the success of a cognitive task depends on three factors: the amount of cognitive resources required to complete the task, the amount of available resources, and the way resources are distributed (Kahneman, 1973). The amount of resources required to complete a task generates a cognitive load which varies with the type and the difficulty of the task. The amount of resources available does not only depend on the individual's capacity for the task but also on the individual's characteristics (age, fatigue, etc.). Finally, the resource distribution system ensures the selection of the relevant information. Cognitive load can therefore increase when resources have to be mobilized or redirected (de Waard, 1996). According to this model, it is impossible to supplement additional tasks under penalty of seeing performance collapse or people disengage from the primary task.

However, it appears impossible, under certain conditions, to simultaneously process several information when it is sometimes impossible to perform an additional task despite the availability of resources. It is, for example, difficult to hold a banal conversation while carrying out mental calculations, even very simple ones. These two tasks theoretically do not exceed the capacities limitation of the individual, but individuals rather finish the conversation before calculating instead of doing it simultaneously. How can we explain this? How can we reconcile the constraints emanating from experimental research with these theoretical models of attention?

With these contradictions in mind, an update of Kahneman's (1973) model has been developed by Wickens (2002). In this revised model, attentional resources are not all the same but would have specific characteristics. These resources would be divided into a system made up of several pools. This multiple attentional resource model describes different types of resources that may be missing when two tasks requiring the same type of resource are performed in parallel. This model helps us to understand the mechanisms behind our difficulties in simultaneously writing or reading a text while having a discussion. Verbal attentional resources compete between these two tasks. To be efficient, we must prioritize them and perform these two tasks one after the other. Wickens' model works very well for almost all our daily actions. Nevertheless, this model, in which attention is a pool and resources are limited, only describes situations of overload. Indeed, this model correctly predicts the performances obtained when the task is too difficult to handle. However, what about situations where individuals have to perform a very simple task? In the previous model, there is no mention of underload situations which are also responsible for the drop in performance (Endsley & Kiris, 1995). In those cases, a large amount of attentional resources should be available, which would thus allow adequate or even better performance for the tasks proposed. Surprisingly, this is not what happens most of the time. Once again, it appears necessary to update this model of multiple resources in order to include cognitive underload situations and better reflect reality.

Manipulating attentional resources would have a cost (de Waard, 1996). Not having to handle too many resources for a task that does not require them would help individuals to save resources. In this model, it is the size of the reservoir itself which varies according to the characteristics of the task (Young & Stanton, 2002). The pool might shrink to roughly adapt to the cost of a task. Best performance for tasks would be achieved when all of the operator's resources are engaged (Lavie, 2010). This is why residual capacities can sometimes disrupt the fluidity in processing by directing resources to other operations, which interfere with the smooth running of the main task. The attentional pool adaptation to the demand of the current task will be done to a certain extent. Indeed, the attentional reservoir will not be able to fully compress or expand infinitely. If that were the case, we would have no trouble thinking about nothing for several minutes. It is very difficult for us to blank our mind even for 20 seconds. There is always a certain amount of available resources which, when the demand for the task is low enough, will be used by redirecting them toward personal thoughts or reflections. This is why the mind-wandering state fits within the framework of this model of malleable resources. Indeed, we often switch from external outputs to our internal world when cognitive demand is low in order to prevent underload and boredom.

Is Attention a Set of Cerebral Networks?

More or less recent researches have revealed that attention is biologically underpinned by a set of brain structures and networks. Together, these networks make possible our ability to process and prioritize the relevant information and allow us to organize our daily life. Specific networks are involved in processing external information, whereas others are dedicated to escape the here and now and sustain the mind-wandering state. The activity of certain networks could therefore provide information on the location of the individual's attentional focus and the degree of attention paid to the current task.

With aim of saving energy and being as efficient as possible, the brain does not have a lawless architecture. Besides being easily divided into several areas (e.g., frontal, parietal, temporal, or occipital lobes), each of brain regions has inner substructures and underpins specific cognitive and/or sensory processes. Visual information processing is located within the occipital lobe, whereas auditory processing mainly depends on the temporal lobe (see Fig. 2.1). Advances in neuroimaging recently provided a great avenue to deeply investigate the brain. At the same time, understanding how the brain regions communicate together has become increasingly obvious as everything we are experiencing in our daily life is dynamic. This conceptually gave birth to the idea of brain networks. By following this rationale, researchers have clearly demonstrated that distinct networks exist. Those networks would be more or less complex and might share same brain structures. Once again, technical advances, especially in functional magnetic resonance imaging (fMRI), allowed emphasizing several tangled networks. However, each network has a

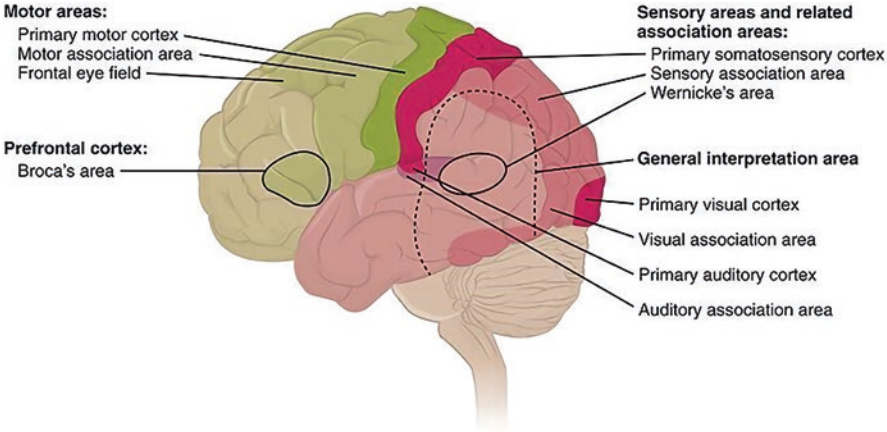

Fig. 2.1 Schematic sectional of the brain representing various areas responsible for sensorial processing

specific structure made up of substructures or brain areas. Those substructures are, most of the time, dedicated to the achievement of specific actions such as transmitting, processing, computing, and integrating electrical information. Subsequently, we will briefly describe two networks which are in charge of attentional processing: the dorsal attentional network (DAN) and the ventral attentional network (VAN). Afterward, we will discuss about the default mode network (DMN) which has been discovered more recently.

According to Corbetta and colleagues, there would be two distinct networks underpinning different needs in terms of attentional capacity (Corbetta & Shulman, 2002). First, the DAN is an attentional network mainly devoted to top-down processes, namely, goal-oriented. Together, the structures that comprise the DAN have a top-down influence on visual attention. That network has close ties with the VAN which is responsible for bottom-up processes with attention. The VAN also allows computing and weighting some information which come from sensory organs. This network is weakly activated during the top-down processing from DAN in order to keep the attentional focus on goals and the short-term visual memory and not to be distracted with irrelevant stimuli. By contrast, when goal-relevant stimuli suddenly pop, the activity of the VAN would increase which, in turn, would allow integrating new information. Therefore, the VAN is mainly devoted to the control of the attentional focus which is guided by sensory organs in order to orient the attention toward salient stimuli (Carretié et al., 2013). For an illustration of how these networks are distributed in the brain, see Fig. 2.2.

The DMN is not in charge of controlling or orienting attention. It is a particular network that has to be particularly considered when studying mind-wandering and more broadly inattention. This network underlies several aspects of cognition (Spreng, 2012) involved in semantic processing or information retrieval from

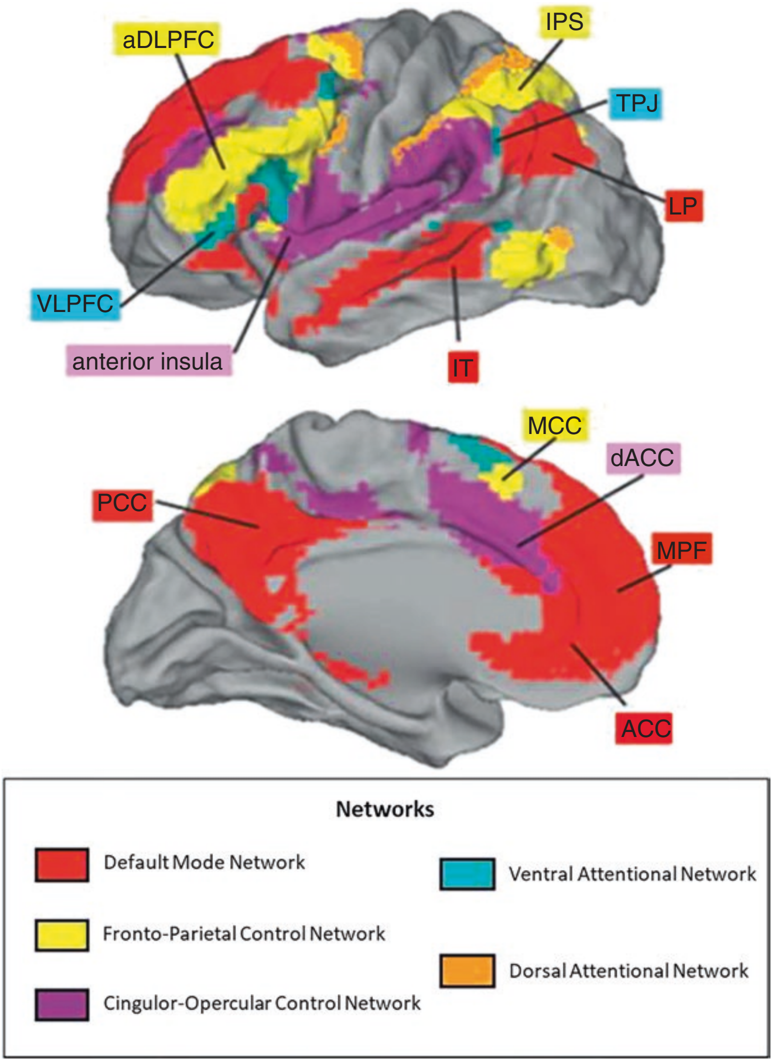

Fig. 2.2 Schematic sectional showing how attentional networks are disseminated in the brain

episodic memory (Rugg & Vilberg, 2013). This default network is more activated during resting states, when we think of ourselves (D'Argembeau et al., 2005; Kelley et al., 2002), when we plan personal events (Spreng et al., 2010), when we have emotional reflections (Engen, 2017), or when we imagine future or past events (Schacter et al., 2007). Neuroscience has provided tremendous proofs of the existence of such a network, and some authors have highlighted a high number of substructures composing it (e.g., Greicius et al., 2003; Raichle et al., 2001).

Default mode network is not only activated during the vagrancy of thought (Stawarczyk et al., 2011) or when we think of something that is of personal importance (Gusnard et al., 2001), but its activation is found to be anticorrelated with that of the brain regions recruited during external sensory processing (e.g., primary visual and auditory cortex as emphasized by Smallwood et al., 2008). Thus, when we think about something else, the activity decreases in regions of the occipital cortex involved in perceptual processing (Gorgolewski et al., 2014). This means that we cannot process information from the outside world and stay focus on our thoughts at the same time. This may seem obvious to anyone who has experienced mind-wandering. However, this is a neurological proof of how our attention works and it sustains models of attention (Kahneman, 1973; Wickens, 2002). The activity of the DMN is thus roughly the opposite to that of the networks responsible for sensory processing, and this network turns out to be independent of the attention ones (Fox et al., 2005). Strong activation of DMN when individuals report daydreaming makes this structure particularly relevant for studying mind-wandering (Christoff et al., 2009; Greicius et al., 2003; Stawarczyk et al., 2011). In addition, the thickness of the regions related to the medial prefrontal cortex and the anterior cingulate cortex, structures belonging to the DMN, would be correlated with the occurrence of MW in individuals (Bernhardt et al., 2014).

What Is Attention?

In summary, these models show that attention is a complex function. Our attentional capacities are limited and attention can be depicted as a pool containing limited resources. These resources can be differently consumed depending on the characteristics of the current task. This is why it is difficult to write a message while holding an oral conversation, these two actions mobilizing the same type of resources (e.g., verbal). In addition, it appears that we are not able to react similarly to a sudden event regardless of how much demanding the task we are doing is. Indeed, the capacity of the attentional pool roughly adapt to the demand of the task performed. Nevertheless, the way we adapt to large variations in the task demand might impact our level of alertness and commitment, which would also be costly in terms of resources and could generate fatigue. In the context of learning, these characteristics must therefore be taken into account. Learning must be moderate over time and not deplete the attentional resources of individuals too quickly. Its difficulty must also be adapted and not present too great variations at the risk of seeing individuals disengage from the task.

Moreover, attention is underpinned by a set of brain structures that are activated preferentially according to what the individual is doing. These complex structures allow quickly processing expected and unexpected information permitting us to properly interact with our environment. Attention would act as filter by deleting information that is not relevant to the individual. In the case of learning, the environment is important. In a noisy setting, it is harder to stay focus because our attention would have trouble filtering all the irrelevant stimuli. This would also generate fatigue. We started to explain the mind-wandering state by showing that it is underpinned by a set of different brain structures. In the next section, we will pay attention to what exactly is mind-wandering, what its daily characteristics are, and how to deal with it.

Mind-Wandering

Mind-wandering (MW) is defined as a shift in the content of thoughts away from the ongoing task toward self-generated thoughts and feelings also known as task-unrelated thoughts (TUTs). This definition, close to the one formulated by Smallwood and Schooler (2015), addresses the problem of attentional shift as well as its persistence known as perceptual decoupling. Perceptual decoupling corresponds to the capacity of the human mind to disconnect our attention from our perceptions, allowing thoughts and feelings to become the fundamental and central elements of conscious thought (Schooler et al., 2011). Therefore, there are two phases in the MW state: a first shift of attention from the outside world to personal thoughts and the maintenance of attention on the train of thought to protect the internal experience also known as perceptual decoupling.

In Everyday Life

Mind-wandering is a common phenomenon that everyone experiences on a daily basis. However, it is difficult to accurately estimate the probability of occurrence of this state. Firstly, individuals are not equal when facing MW; some experience it very often every day and others very little. MW tends to be more present in young people and children than in the elderly ones, but it seems that there is no difference between men and women (Burdett et al., 2017; Giambra, 1989, 1993). Fatigue, alcohol consumption, and psychotropic substances are likely to promote the emergence of this state (Kane et al., 2007; Sayette et al., 2009). In case we might doubt that MW arises in the cerebrum, it is also possible for a given time period to artificially increase or reduce the emergence of MW by stimulating areas in the brain (Axelrod et al., 2015; Kajimura & Nomura, 2015), and the thickness of areas are likely to predict the emergence of MW (Bernhardt et al., 2014). Moreover, the working memory capacity is likely to modulate the sensitivity of individuals to this state by increasing or decreasing the occurrence of MW depending on the kind of task people are asked to do (Kane et al., 2007; Levinson et al., 2012; Rummel & Boywitt, 2014; Pepin, 2018). Moreover, the mindfulness trait of an individual could lead to different level of MW: mindful people tends to have fewer TUTs in both demanding and undemanding tasks (Ju & Lien, 2018). Thus, we might not be equal when facing MW. Considering learning, some students may be susceptible to be more often inattentive because of their cerebral and personal characteristics, while others may have no trouble being focused for hours.

Characteristics of the current activity are also important to apprehend the occurrence of MW. A cognitively inexpensive task, whether it is straightforwardly easy, a repetitive task, or a familiar one, will generate more inattention than a more complex one which will require engagement and concentration (He et al., 2011; Kam et al., 2014; Dehais et al., 2020). For example, when driving a car, the emergence of MW increases with the practice of the activity (Yanko & Spalek, 2013) and more generally with the level of expertise (Cunningham et al., 2000; Smallwood et al., 2004). This could explain why a known journey (e.g., home-to-work travel) is likely to be more dangerous for the driver than a new one (Burdett et al., 2017; Yanko & Spalek, 2013).

It is difficult to be precise when quantifying the percentage of time we spend thinking about something else than our main activity. The occurrence of MW has been probed with different daily tasks such as a memory, reflection, reading, etc. Results obtained range from 25% (Kane et al., 2007; Spronken et al., 2016; Stawarczyk et al., 2013) to 40% (Yanko & Spalek, 2014), 45% (Ottaviani et al., 2013), and 47% (Killingsworth & Gilbert, 2010) up to more than 50% of the time (Kam & Handy, 2014). These differences can arise, as we have seen, from heterogeneous populations, heterogeneous experimental paradigms, different tasks, or even from different definitions given to MW. So, how can we properly estimate and limit the chances of mistaking the presence of MW? The only study that did not offer an ancillary task, but tried to measure the occurrence of MW in all of daily life tasks, is the one conducted by Killingsworth and Gilbert (2010). Several times a day, 2250 people from dozens of different countries (although 74% of the respondents were American) were sporadically stopped during their daily life and asked to report what they were doing. In details, they were instructed to assess the orientation of their thoughts (i.e., focused on the outside vs. internal world) and their time-related and emotional content (i.e., past vs. present vs. future-oriented and neutral vs. negative vs. positive). People reported that their attention was focused on something else than what they were currently doing for 46.9% of the time. Surprisingly, this result varies little with the type of activity performed, and each activity is performed with TUTs at least 30% of the time except making love (Killingsworth & Gilbert, 2010). This means that about half the time, individuals are not focused on their activity. By interrupting someone in his daily life, we have almost 50-50 chance to find him thinking about something else than whatever he is currently doing. Although people are not equally affected by MW, results obtained in this study reflect how much this state is regular in our daily life and that it should not be left behind when studying learning processes. For example, people tend to have more TUTs over the duration of a lecture when viewed in video format, while those who viewed it live did not (Wammes & Smilek, 2017).

MW might make us break a glass or miss a step on the stairs and, at worst, make us have a serious car accident. So, why does our mind escape from reality so often while we know the dangerousness of inattention? This takeover of our attention, without permission, may therefore seem astonishing. However, MW is very present in everyday life. The evolutionary approach leads us to think that, if a characteristic has endured up till now and has not disappeared yet, it is because of its benefits for the individual. MW might not be an exception.

Benefits

Mind-wandering has many advantages. It helps us planning our lives by reminding us the appointment we had forgotten later in the day, resolving our daily problems, or building a shopping list during housework. Einstein even said: “Why is it I always have my best ideas while shaving?”. How many scientific, artistic, or political ideas emerged when people were cooking, driving, or even in the shower or to the toilet? Indeed, these activities tend to be the most automatically performed (Killingsworth & Gilbert, 2010). Without constraint on our cognition, our mind tends to freely stray (Andrews-Hanna et al., 2017). So, to the question “why does not the mind stay perfectly focused on the tasks being performed, even on the most routine?” The answer could simply be that our minds can indulge in it and that our complex brains are not programmed to leave free resources in the attentional pool. Indeed, each time that we do nothing or we are performing an easy task, our minds drift away to self-generated thoughts, even if we are not aware of it. Reversely, when our mind is busy but our body has nothing to do, we tend to perform automatic and physical task such as playing with a pen or pacing in the living room during a phone call.

During MW, our thoughts become both the direct focus of our attention and the center of our conscious experience (Schooler et al., 2011). This might allow us to be more creative after performing a short period of automatic task (Baird et al., 2012) or to be more efficient in solving a complex problem (Abadie et al., 2013). MW appears to act in the background of the mind while the individual performs a secondary task. MW status would also allow us to organize our lives without having to actively think about it by planning future events or trying to solve our personal problems (Mooneyham & Schooler, 2013; Smallwood & Schooler, 2015). The MW state would also underlie important functions without which our lives would be very different: the possibility of extracting ourselves from the here and now, imagining other places and moments (Nyberg et al., 2010), and even the ability to infer what others think or feel (Frith & Frith, 2005). Others postulate that MW is essential for all creative thinking, which is the basis of language and any form of complex cognition. MW is also an easy and fun way to get rid of stress and boredom (Corballis, 2015).

The mind-wandering state would therefore be useful for individuals by allowing them to be more creative, escaping from their immediate environment, imagining other places and moments, or solving personal problems. However, by directing our attention toward our thoughts or our personal problems, we disconnect from the external environment. In turn, it would impact the performance of the primary task and therefore, the harmful effects of MW would emerge.

Drawbacks

By drawing in attentional resources, MW leads to poor performance in a multitude of everyday tasks (Smallwood & Schooler, 2006). It turns out that MW impairs comprehension during silent or aloud reading tasks (McVay & Kane, 2012; Schooler, 2004; Unsworth & McMillan, 2013). Driving a car requires collecting, processing, and encoding information. Obviously, given the risks of body injury, the risks of attentional dropout during MW are therefore even more damaging for drivers (Galera et al., 2012) as compared to silent reading.

MW would particularly degrade performance of tasks requiring supervision and immediate encoding of information (Ruby et al., 2013) which could be problematical in a learning context. This is also a reason why MW should be taken into account when studying learning processes so as to frame its effect as much as possible.

A Halftone State

As previously described, our attention tends to drift away from the task we are currently doing to our personal thoughts leading to a higher risk of error. Unfortunately, the reasons that keep our attention away from the task at hand are quite mysterious. As we have said, MW has an evolving role in planning, organizing, and solving our personal problems (Buckner & Vincent, 2007; Smallwood et al., 2009; Smallwood & Schooler, 2006); attention would therefore be devoted to what is the most relevant to the individual at any given time (Randall et al., 2014). Consequently, attention may shift to personal thoughts only when we need it and when the situation allows it (e.g., when the task is simple and can be performed automatically/easily).

Considering the aforementioned models of attention and given the characteristics of MW, it is likely that this state soaks individuals' attentional resources to feed internal trains of thoughts. During a learning exercise, the individual experiencing MW would therefore be less able to focus on the task or the speaker; his resources are no longer allocated to the main task but used to fuel his thoughts (Baird et al., 2011). He might think of what to do after class, how to relax, etc. The presence of MW might therefore cause learning difficulties because of the disconnection between attention and environment, what we previously described as perceptual decoupling.

Perceptual Decoupling

MW is a two-step state. A first drift of attention far from the task we are doing followed by the maintenance of attention protecting the new internal experience, called perceptual decoupling. Perceptual decoupling is a fundamental and essential characteristic of MW. During this state, our attention is focused on our thoughts and/or our personal feelings. It corresponds to a disconnection of attention away from sensory inputs and perceptions (Schooler et al., 2011; Smallwood & Schooler, 2015). As we saw in the previous section, perceptual decoupling is maintained by the activity of different brain structures and more specifically by the default mode network. Other evidence of perceptual decoupling can be found by examining cortical activations of various areas in the brain. During MW, the brain activity in the cortical areas is reduced (Chaparro, 2015), meaning that information processing is more superficial when we direct our attention toward our thoughts as compared to the external world.

Perceptual decoupling reflects the dissociation between the individual and its immediate environment. In Treisman's (1969) attentional model, attention is seen as a filter attenuating irrelevant information. Perceptual decoupling could perfectly match the features of this filter: when individual focuses its attention on their internal world, its thoughts become the most relevant element. Information from outside is therefore attenuated so as not to disturb the flow of thoughts. During this phenomenon, people's visual exploration is reduced (He et al., 2011) and certain stimuli are ignored (Yanko & Spalek, 2014). This might be due to the deflection of resources to maintain the train of thoughts and the switch of activation between networks responsible for active attention (DAN and VAN) and the default mode network. Perceptual decoupling is a first explanation for the performance decrease associated with MW (Smallwood & Schooler, 2006; Unsworth & McMillan, 2013). But this state is not a simple reorientation of attention; the thoughts that are simultaneously generated must be fed to exist and persist. This is also why we don't have a lot of wandering thoughts while performing a difficult task; all the resources are allocated to succeed in the task. Otherwise, the lack of resources to perform the two tasks would generate errors and would get us out of MW by realizing that we are experiencing TUTs.

It turns out that characteristics of thoughts could be an essential factor in estimating their degree of disturbance, and part of the current research aims to explain these disparities. The content of our own thoughts refers to the message they generate. When we are in a certain state, in a negative mood, for instance, we will tend to think to different things compared with when we are in a more positive state. Our thoughts are as spontaneous as they can include a wide spectrum of features and content. The content regulation hypothesis carries the idea that the content of the thoughts and the experience lived by the individual will define the impact of this state on the performance of the task in progress (Andrews-Hanna et al., 2013; Smallwood & Andrews-Hanna, 2013). When considering MW, it should be noted that not all types of thinking are the same. There is a multitude of different types of thinking, which could be classified according to many characteristics based on the content of thoughts (temporality, intentionality, emotional valence, consciousness, purpose of thoughts, etc.). The next section will focus on some factors used to classify thoughts.

To Classify Thoughts

Temporality and Emotion

First of all, emotional content and temporal orientation of wandering thoughts are not random. Several researches made clear the existence of prospective and retrospective bias. These biases represent strong links between the temporality of thoughts and their emotional content (Smallwood & O'Connor, 2011). The prospective bias emphasizes that a majority of wandering thoughts are future-oriented (Berthié et al., 2015; Smallwood et al., 2009). This is explained by the fact that MW has a relevant function in planning and solving personal problems (Buckner & Vincent, 2007; Smallwood & Schooler, 2006). The proportion of future-oriented thoughts varies across studies, but seems to be around 50% of all TUTs (Baird et al., 2011; Berthié et al., 2015). This means that, on average, one in two thoughts unrelated to what the individual is doing is directed to future events. We saw that people tend to think to something else than what they are currently doing for around half the time. This would mean that you have one chance out of four to interrupt someone during his task while he is thinking of something that has not happened yet.

The proportion of past-oriented thoughts is around 12%, while present-oriented thoughts represent around 30% (Baird et al., 2011). Thoughts without temporal orientation would represent around 11% of thoughts (Smallwood & Schooler, 2015) and would be different from present-oriented thoughts (see Fig. 2.3). These might be philosophical thoughts or thinking about the spelling of a word, for example. Present-oriented thoughts are often amalgamated with the thoughts without

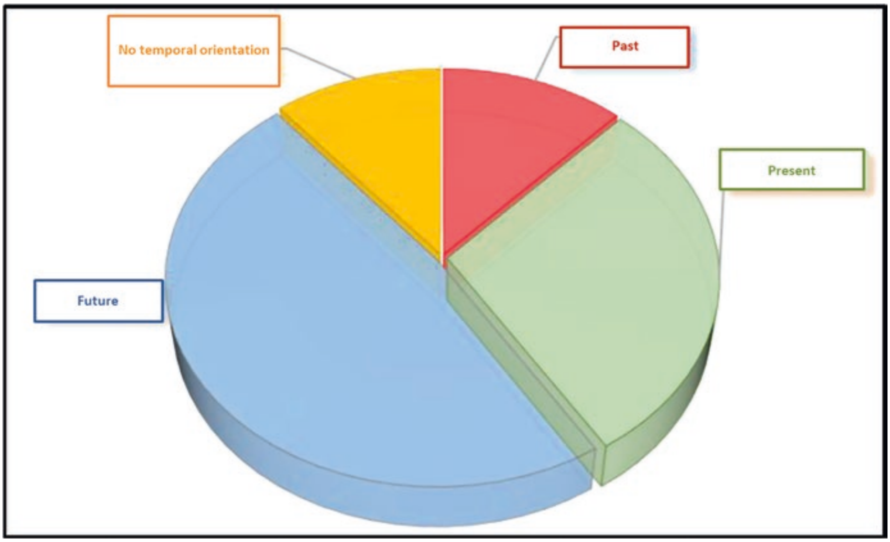

Fig. 2.3 Diagram showing proportion of temporally oriented thoughts

temporal focus which generates inaccuracies in the quantification of temporally oriented thoughts. Generally, thoughts unrelated to the individual's activity tend to be future-oriented and these thoughts tend to be positive (Ruby et al., 2013; Spronken et al., 2016).

Intentionality and Consciousness

Among all thoughts unrelated to the task at hand are "spontaneous thoughts," which supplant task-directed attention for unconscious and unintentional thoughts (Christoff, 2012). The group of "spontaneous thoughts" is not uniform and brings together, within it, the vagrancy of thought, daydreams, or even episodes of involuntary autobiographical recall. These thoughts are neither conscious (until the individual realizes it) nor intentional. In contrast to these thoughts that spontaneously burst into the mind of the individual, intentional thoughts unrelated to the main activity have been described.

Immersing ourselves intentionally in task-unrelated thoughts assumes that we feel able of performing two tasks in parallel. We feel confident enough to allow us to disconnect from the environment. Intentionality seems to be an important factor for wandering thoughts categorization. Indeed, intentional TUTs would not be underpinned by the same cerebral substructures as thoughts arising spontaneously. Indeed, coupling the frontoparietal control network with the default network (Golchert et al., 2017) would generate separate states (Smith et al., 2006). These two states appear to result from a particular brain function, underlying separate cognitive processes that could be the source of different degrees of interference with learning. In the same way, conscious and unconscious task-unrelated thoughts would involve different brain regions (Smith et al., 2006) and might have different impact on people, drivers, for example (Pepin et al., 2018).

Conclusion

At first glance, we might be tempted to put into perspective the harmful impact of mind-wandering during learning: it cannot be very dangerous to think of something else for a few moments. Actually, most of the time, MW has no negative impact. However, it can be problematic during certain activity such as driving or learning with various levels of negative effect and potential risk according to the task we are doing. We now know that MW impairs comprehension reading. Moreover, a more difficult task, as it is often observed during some learning stages, is associated with more MW (Soemer et al., 2019). By drawing into working memory resources, MW prevents the ability to refresh information from the outside world (Kam et al., 2014), and investigating the presence of MW during learning processes appears to be a significant issue.

Investigating the characteristics of MW and its functioning appears as something exciting and primary to better understand performance in a large set of tasks. In the previous sections, we have seen that MW is a particular state since it is experienced by everyone on a daily basis. It has been shown that the degree of interference from MW would be different depending on the content of thoughts and the context in which it occurs. It turns out that not all thoughts seem to have the same degree of interference with the individual's main activity. Thoughts related to the organization of our daily life could thus be more or less disturbing according to their emotional content (positive or negative) or their temporality. Mentally building a shopping list or thinking of not forgetting to pick up the kids from school might not have the same impact. In the same vein, for kids who tried engaging in learning processes, thinking about the yesterday test or the football game in the evening may not prevent learning in the same way. Moreover, we know that kids tend to experience more MW than the older one, raising even more the question of the role of this state for them.

A section of contemporary research seeks to dissect these characteristics to study the impact of these thoughts on humans, using tools such as electroencephalography, eye tracking, heart rate analysis, etc. In the future, perhaps we will be able to facilitate learning by orienting its content so as to limit its presence or even prevent MW during learning phases so that kids and more broadly people will not suffer its harmful effects.

References

Abadie, M., Waroquier, L., & Terrier, P. (2013). Gist memory in the unconscious-thought effect. *Psychological Science, 24*(7), 1253–1259.

Andrews-Hanna, J., Kaiser, R. H., Turner, A., Reineberg, A., Godinez, D., Dimidjian, S., & Banich, M. (2013). A penny for your thoughts: Dimensions of self-generated thought content and relationships with individual differences in emotional wellbeing. *Frontiers in Psychology, 4*, 900.

Andrews-Hanna, Jessica, Irving, Z., Fox, K., Spreng, N., & Christoff, K. (2017). The neuroscience of spontaneous thought: an evolving, interdisciplinary field. arXiv:1704.02533.

Axelrod, V., Rees, G., Lavidor, M., & Bar, M. (2015). Increasing propensity to mind-wander with transcranial direct current stimulation. *Proceedings of the National Academy of Sciences, 112*(11), 3314–3319.

Baird, B., Smallwood, J., & Schooler, J. (2011). Back to the future: Autobiographical planning and the functionality of mind-wandering. *Consciousness and Cognition, 20*(4), 1604–1611.

Baird, B., Smallwood, J., Mrazek, M., Kam, J., Franklin, M., & Schooler, J. (2012). Inspired by distraction: mind wandering facilitates creative incubation. *Psychological Science, 23*(10), 1117–1122.

Bernhardt, B., Smallwood, J., Tusche, A., Ruby, F. J. M., Engen, H. G., Steinbeis, N., & Singer, T. (2014). Medial prefrontal and anterior cingulate cortical thickness predicts shared individual differences in self-generated thought and temporal discounting. *NeuroImage, 90*, 290–297.

Berthié, G., Lemercier, C., Paubel, P.-V., Cour, M., Fort, A., Galéra, C., Lagarde, E., Gabaude, C., & Maury, B. (2015). The restless mind while driving: Drivers' thoughts behind the wheel. *Accident; Analysis and Prevention, 76*, 159–165.

Broadbent, D. E. (1958). *Perception and communication*. Pergamon Press.

Buckner, R., & Vincent, J. (2007). Unrest at rest: Default activity and spontaneous network correlations. *NeuroImage, 37*(4), 1091–1096.

Burdett, B. R. D., Charlton, S. G., & Starkey, N. J. (2017). Inside the commuting driver's wandering mind. *Transportation Research Part F: Traffic Psychology and Behaviour*. https://doi.org/10.1016/j.trf.201

Carretié, L., Albert, J., López-Martín, S., Hoyos, S., Kessel, D., Tapia, M., & Capilla, A. (2013). Differential neural mechanisms underlying exogenous attention to peripheral and central distracters. *Neuropsychologia, 51*(10), 1838–1847.

Chaparro, R. A. H. (2015). *Behavioral and neural correlates of spontaneous attentional decoupling: towards an understanding of mind wandering*. PhD thesis. Université Pierre et Marie Curie.

Christoff, K. (2012). Undirected thought: Neural determinants and correlates. *Brain Research, 1428*, 51–59.

Christoff, K., Gordon, A. M., Smallwood, J., Smith, R., & Schooler, J. W. (2009). Experience sampling during fMRI reveals default network and executive system contributions to mind wandering. *Proceedings of the National Academy of Sciences, 106*(21), 8719–8724.

Corballis, M. C. (2015). *The wandering mind: What the brain does when you're not looking*. University of Chicago Press.

Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience, 3*(3), 201.

Cunningham, S., Scerbo, M. W., & Freeman, F. G. (2000). The electrocortical correlates of daydreaming during vigilance tasks. *Journal of Mental Imagery, 24*(1–2), 61–72.

D'Argembeau, A., Collette, F., Van der Linden, M., Laureys, S., Del Fiore, G., Degueldre, C., Luxen, A., & Salmon, E. (2005). Self-referential reflective activity and its relationship with rest: A PET study. *NeuroImage, 25*(2), 616–624.

Dehais, F., Lafont, A., Roy, R. N., & Fairclough, S. (2020). A neuroergonomics approach to mental workload, engagement and human performance. *Frontiers in Neuroscience, 14*, 1–17.

de Waard, D. (1996). *The measurement of drivers' mental workload*. Groningen University, Traffic Research Center.

Endsley, M. R., & Kiris, E. O. (1995). The out-of-the-loop performance problem and level of control in automation. *Human Factors, 37*(2), 381–394.

Engen, H. G. (2017). *On the endogenous generation of emotion*. PhD thesis. Max Planck Institute for Human Cognitive and Brain Sciences.

Fox, M., Snyder, A., Vincent, J., Corbetta, M., Van Essen, D., & Raichle, M. (2005). The human brain is intrinsically organized into dynamic, anticorrelated functional networks. *Proceedings of the National Academy of Sciences of the United States of America, 102*(27), 9673–9678.

Frith, C., & Frith, U. (2005). Theory of mind. *Current Biology, 15*(17), R644–R645.

Galera, C., Orriols, L., M'Bailara, K., Laborey, M., Contrand, B., Ribereau-Gayon, R., Masson, F., Bakiri, S., Gabaude, C., Fort, A., Maury, B., Lemercier, C., Cours, M., Bouvard, M.-P., & Lagarde, E. (2012). Mind wandering and driving: A responsibility case-control study. *British Medical Journal, 345*, 7p.

Giambra, L. M. (1989). Task-unrelated thought frequency as a function of age: A laboratory study. *Psychology and Aging, 4*(2), 136.

Giambra, L. M. (1993). The influence of aging on spontaneous shifts of attention from external stimuli to the contents of consciousness. *Experimental Gerontology, 28*(4), 485–492.

Golchert, J., Smallwood, J., Jefferies, E., Seli, P., Huntenburg, J. M., Liem, F., … Margulies, D. S. (2017). Individual variation in intentionality in the mind-wandering state is reflected in the integration of the default-mode, fronto-parietal, and limbic networks. *NeuroImage, 146*, 226–235.

Gorgolewski, K. J., Lurie, D., Urchs, S., Kipping, J. A., Craddock, R. C., Milham, M. P., … Smallwood, J. (2014). A correspondence between individual differences in the brain's intrinsic functional architecture and the content and form of self-generated thoughts. *PLoS One, 9*(5), e97176.

Greicius, M., Krasnow, B., Reiss, A. L., & Menon, V. (2003). Functional connectivity in the resting brain: A network analysis of the default mode hypothesis. *Proceedings of the National Academy of Sciences of the United States of America, 100*(1), 253–258.

Gusnard, D., Akbudak, E., Shulman, G., & Raichle, M. (2001). Medial prefrontal cortex and self-referential mental activity: Relation to a default mode of brain function. *Proceedings of the National Academy of Sciences, 98*(7), 4259–4264.

He, J., Becic, E., Lee, Y.-C., & McCarley, J. S. (2011). Mind wandering behind the wheel: Performance and oculomotor correlates. *Human Factors, 53*(1), 13–21.

Ju, Y.-J., & Lien, Y.-W. (2018). Who is prone to wander and when? Examining an integrative effect of working memory capacity and mindfulness trait on mind wandering under different task loads. *Consciousness and Cognition, 63*, 1–10.

Kahneman, D. (1973). *Attention and effort* (Vol. 1063). Prentice-Hall.

Kajimura, S., & Nomura, M. (2015). Decreasing propensity to mind-wander with transcranial direct current stimulation. *Neuropsychologia, 75*, 533–537.

Kam, J., & Handy, T. C. (2014). Differential recruitment of executive resources during mind wandering. *Consciousness and Cognition, 26*, 51–63.

Kam, J., Nagamatsu, L. S., & Handy, T. C. (2014). Visual asymmetry revisited: Mind wandering preferentially disrupts processing in the left visual field. *Brain and Cognition, 92C*, 32–38.

Kane, M. J., Brown, L. H., McVay, J. C., Silvia, P. J., Myin-Germeys, I., & Kwapil, T. R. (2007). For whom the mind wanders, and when: An experience-sampling study of working memory and executive control in daily life. *Psychological Science, 18*(7), 614–621.

Kelley, W. M., Macrae, C. N., Wyland, C. L., Caglar, S., Inati, S., & Heatherton, T. F. (2002). Finding the self? An event-related fMRI study. *Journal of Cognitive Neuroscience, 14*(5), 785–794.

Killingsworth, M. A., & Gilbert, D. T. (2010). A wandering mind is an unhappy mind. *Science, 330*(6006), 932–932.

Lavie, N. (2010). Attention, distraction, and cognitive control under load. *Current Directions in Psychological Science, 19*(3), 143–148.

Levinson, D., Smallwood, J., & Davidson, R. J. (2012). The persistence of thought: Evidence for a role of working memory in the maintenance of task-unrelated thinking. *Psychological Science, 23*(4), 375–380.

McVay, J., & Kane, M. J. (2012). Why does working memory capacity predict variation in reading comprehension? On the influence of mind wandering and executive attention. *Journal of Experimental Psychology: General, 141*(2), 302.

Mooneyham, B., & Schooler, J. W. (2013). The costs and benefits of mind-wandering: A review. *Canadian Journal of Experimental Psychology-Revue Canadienne De Psychologie Expérimentale, 67*(1), 11–18.

Nyberg, L., Kim, A. S. N., Habib, R., Levine, B., & Tulving, E. (2010). Consciousness of subjective time in the brain. *Proceedings of the National Academy of Sciences, 107*(51), 22356–22359.

Ottaviani, C., Shapiro, D., & Couyoumdjian, A. (2013). Flexibility as the key for somatic health: From mind wandering to perseverative cognition. *Biological Psychology, 94*(1), 38–43.

Pepin, G. (2018). *Recherche d'indicateurs d'inattention en conduite automobile: apports des mesures physiologiques et comportementales*. PhD thesis, 231p.

Pepin, G., Malin, S., Jallais, C., Moreau, F., Fort, A., Navarro, J., Ndiaye, D., & Gabaude, C. (2018). Do distinct mind wandering differently disrupt drivers? Interpretation of physiological and behavioral pattern with a data triangulation method. *Consciousness & Cognition, 62*, 69–81.

Raichle, M., MacLeod, A. M., Snyder, A., Powers, W., Gusnard, D., & Shulman, G. (2001). A default mode of brain function. *Proceedings of the National Academy of Sciences of the United States of America, 98*(2), 676–682.

Randall, J., Oswald, F. L., & Beier, M. E. (2014). Mind-wandering, cognition, and performance: A theory-driven meta-analysis of attention regulation. *Psychological Bulletin, 140*(6), 1411–1431.

Ruby, F., Smallwood, J., Engen, H., & Singer, T. (2013). How self-generated thought shapes mood – The relation between mind-wandering and mood depends on the socio-temporal content of thoughts. *PLoS One, 8*(10), e77554.

Rugg, M., & Vilberg, K. L. (2013). Brain networks underlying episodic memory retrieval. *Current Opinion in Neurobiology, 23*(2), 255–260.

Rummel, J., & Boywitt, C. D. (2014). Controlling the stream of thought: Working memory capacity predicts adjustment of mind-wandering to situational demands. *Psychonomic Bulletin & Review, 21*(5), 1309–1315.

Sayette, M., Reichle, E. D., & Schooler, J. W. (2009). Lost in the sauce: The effects of alcohol on mind wandering. *Psychological Science, 20*(6), 747–752.

Schacter, D., Addis, D. R., & Buckner, R. L. (2007). Remembering the past to imagine the future: the prospective brain. *Nature Reviews Neuroscience, 8*(9), 657.

Schooler, J. (2004). Zoning out while reading: Evidence for dissociations between experience and Metaconsciousness. In J. W. Schooler, E. D. Reichle, & D. V. Halpern (Eds.), *Thinking and seeing: Visual metacognition in adults and children* (p. 203). MIT Press.

Schooler, J., Smallwood, J., Christoff, K., Handy, T. C., Reichle, E. D., & Sayette, M. A. (2011). Meta-awareness, perceptual decoupling and the wandering mind. *Trends in Cognitive Sciences, 15*(7), 319–326.

Smallwood, J., & Andrews-Hanna, J. (2013). Not all minds that wander are lost: the importance of a balanced perspective on the mind-wandering state. *Frontiers in Psychology, 4*, 441.

Smallwood, J., & O'Connor, R. C. (2011). Imprisoned by the past: Unhappy moods lead to a retrospective bias to mind wandering. *Cognition & Emotion, 25*(8), 1481–1490.

Smallwood, J., & Schooler, J. W. (2006). The restless mind. *Psychological Bulletin, 132*(6), 946–958.

Smallwood, J., & Schooler, J. W. (2015). The science of mind wandering: Empirically navigating the stream of consciousness. *Annual Review of Psychology, 66*, 487–518.

Smallwood, J., Davies, J. B., Heim, D., Finnigan, F., Sudberry, M., O'Connor, R., & Obonsawin, M. (2004). Subjective experience and the attentional lapse: Task engagement and disengagement during sustained attention. *Consciousness and Cognition, 13*(4), 657–690.

Smallwood, J., Beach, E., Schooler, J. W., & Handy, T. C. (2008). Going AWOL in the brain: Mind wandering reduces cortical analysis of external events. *Journal of Cognitive Neuroscience, 20*(3), 458–469.

Smallwood, J., Nind, L., & O'Connor, R. C. (2009). When is your head at? An exploration of the factors associated with the temporal focus of the wandering mind. *Consciousness and Cognition, 18*(1), 118–125.

Smith, R., Keramatian, K., Smallwood, J., Schooler, J., Luus, B., & Christoff, K. (2006). Mind-wandering with and without awareness: An fMRI study of spontaneous thought processes. In proceedings of the annual meeting of the cognitive science society (Vol. 28).

Soemer, A., Idsardi, H. M., Minnaert, A., & Schiefele, U. (2019). Mind wandering and reading comprehension in secondary school children. *Learning and Individual Differences, 75*, 101778.

Spreng, N. (2012). The fallacy of a "task-negative" network. *Frontiers in Psychology, 3*, 145.

Spreng, N., Stevens, W. D., Chamberlain, J. P., Gilmore, A. W., & Schacter, D. L. (2010). Default network activity, coupled with the frontoparietal control network, supports goal-directed cognition. *NeuroImage, 53*(1), 303–317.

Spronken, M., Holland, R. W., Figner, B., & Dijksterhuis, A. (2016). Temporal focus, temporal distance, and mind-wandering valence: Results from an experience sampling and an experimental study. *Consciousness and Cognition, 41*, 104–118.

Stawarczyk, D., Majerus, S., Maquet, P., & D'Argembeau, A. (2011). Neural correlates of ongoing conscious experience: Both task-unrelatedness and stimulus-independence are related to default network activity. *PLoS One, 6*(2), e16997.

Stawarczyk, D., Cassol, H., & D'Argembeau, A. (2013). Phenomenology of future-oriented mind-wandering episodes. *Frontiers in Psychology, 4*, 425.

Treisman, A. (1969). Strategies and models of selective attention. *Psychological Review, 76*(3), 282.

Unsworth, N., & McMillan, B. D. (2013). Mind wandering and reading comprehension: Examining the roles of working memory capacity, interest, motivation, and topic experience. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 39*(3), 832.

Wammes, J. D., & Smilek, D. (2017). Examining the influence of lecture format on degree of mind wandering. *Journal of Applied Research in Memory and Cognition., 6*(2), 174–184.

Was, C. A., Hollis, R. B., & Dunlosky, J. (2019). Do students understand the detrimental effects of mind wandering during online learning? *Computers & Education, Volume, 135*, 113–122.

Wickens, C. (2002). Multiple resources and performance prediction. *Theoretical Issues in Ergonomics Science, 3*(2), 159–177.

Yanko, M., & Spalek, T. M. (2013). Route familiarity breeds inattention: A driving simulator study. *Accident Analysis & Prevention, 57*, 80–86.

Yanko, M., & Spalek, T. M. (2014). Driving with the wandering mind: the effect that mind-wandering has on driving performance. *Human Factors, 56*(2), 260–269.

Young, M., & Stanton, N. A. (2002). Malleable attentional resources theory: A new explanation for the effects of mental underload on performance. *Human Factors, 44*(3), 365–375.