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Opinion Piece

Why Covid-19 might be making us lose our sense of time….

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Time is a peculiar sense. Objectively it passes at a constant linear rate. Throughout our lives, each second, minute, hour and day have a fixed physical duration. Our *experience* of time however deviates markedly from this. Sometimes an hour can feel like a day and a day as long as a week. Conversely, at other times an hour can whizz by in what feels like a minute and a two-week holiday passes by in a blur. The hands of life's clock seem to have their own ever-changing pace.

Coronavirus has brought the fluidity of time into focus for many people. Since the UK-wide lockdown which began in March, social media, newspapers and magazines have discussed the idea that covid-19 has somehow changed our sense of time. Popular memes depict cartoon calendars where all months are April and colleagues refer to everyday as "Blursday". This loss of time does not appear to be simply anecdotal. Research studies conducted in the UK (Ogden, 2020) and France (Droit-Volet et al., 2020) confirmed that people experienced widespread and significant distortions to the passage of time during lockdown.

To understand time experience during the UK lockdown, I asked people to rate the speed at which time was passing in relation to normal (prior to lockdown). 80% of people reported distortions to the passage of time during lockdown. Of that 80%, about half reported that time was passing more quickly than normal, and half reported that time was passing more slowly than normal. Analysis of the factors which affected the subjective passage of time during lockdown suggested that a "fast" lockdown was associated with decreasing age, greater satisfaction with social interactions, reduced stress and increased task load. Conversely, a slow lockdown was associated with increasing age, particularly being over the age of 65, decreased satisfaction with social interactions, decreased task load and increased stress. Factors such as depression, anxiety and perceived personal risk from covid-19 were not predictive of the speed of the passage of time during the lockdown period.

Using a slightly different methodology in which people rated the speed of the passage of time before lockdown, now, today and for the last week, Droit-Volet et al., (2020) also demonstrated widespread distortion to time during the French national lockdown. Interestingly, unlike in the UK, people in France were more likely to experience a slowing of the passage of time during lockdown in comparison with normal. There were also some territorial differences in the factors which predicted how time was experienced. Although increasing stress and age were associated with a slowing of time, mediation analysis suggested that increases in boredom and sadness were the primary predictors of a slowing of time during the French lockdown.

At first glance, one might be tempted to say the above results are unsurprising. Since the 1960s (and seemingly long before the advent of ethics panels) case studies and small-scale observational studies have demonstrated that removal from normal daily life can cause significant distortion to the passage of time. For example, Thor and Crawford (1964) observed that families locked inside a nuclear fallout bunker for 14 days reported a distorted sense of time during their period of confinement. Similar observations were made when children aged 7- 12 years were isolated in a room for six days (Crawford & Thor, 1967). Most famously perhaps, in a series of case studies, Siffre (1964) repeatedly demonstrated that isolation in a cave, at times for over 40 days, resulted in significant distortion to his sense of time.

Unlike the studies of temporal experience during the pandemic however, the studies by Siffre, Thor and Crawford removed all external temporal markers from participants. This included the removal of watches and clocks from the places of confinement and the prevention of any natural light entering the environment. Therefore, the distortions to time observed perhaps primarily reflect the loss of temporal markers rather than the effects of isolation and environment. These studies therefore tell us that external temporal markers are critical to maintaining an accurate sense of time and that without them, a loss of time is significant and somewhat inevitable. However, they do not tell us how or why time is distorted when external temporal markers are present. The research conducted during the covid-19 pandemic therefore offered a unique opportunity to understand what happens to time then the social environment changes, but temporal markers are still in place. So why does the passage of time distort even in the presence of clocks and watches?

Unlike vision, hearing, taste, touch and smell, we do not appear to have a specific organ dedicated to our sense of time. This is perhaps because time is experienced as a property of other objects and actions and feelings. For example, when we think about time, or make judgments about time, we are almost always referring to the perceived duration of a specific event or stimulus. It is difficult to imagine a situation in which time is experienced in the absence of a stimulus to experience it through. Indeed, the absence of an obvious and specific sense organ has contributed to the difficulties neuroscientists and psychologists have faced in identifying specifically how we perceive time and understanding why time becomes distorted. Nonetheless, cognitive, affective and brain-based theories have emerged to explain temporal distortions. Below I briefly review four of these.

1. *Emotional arousal*

Craig (2009) developed a homeostatic model of timing to explain temporal distortions. Studies consistently show that emotional arousal distorts our perception of time. In laboratory studies of short duration ranges (< 5 seconds), highly arousing negatively valenced stimuli are consistently perceived as lasting for longer than neutral stimuli of the same duration (see Droit-Volet & Meck, 2007; Lake, LaBar & Meck, 2016 for reviews). Emotion also distorts time in real world settings with people being more likely to report that the present moment is passing more quickly than normal when they are highly aroused and experiencing positive affect

(Droit-Volet & Wearden, 2015). Conversely, depression is associated with a slowing of time and the sensation that the days are dragging by (e.g. Blewett, 1992).

Craig (2009) proposed that emotional distortions to time occur because of the dual role of the anterior insular cortex (AIC) in time perception and homeostasis. The AIC is involved in maintaining homeostatic regulation of the autonomic nervous system (ANS). During homeostatic regulation, the AIC is asymmetrically activated; right-side activation is associated with increased activity of the sympathetic branch (SNS) of the ANS whereas the left-side is associated with reduced SNS activity and increased activity of the parasympathetic branch (PSNS) (see Craig, 2002). There is also evidence that the AIC is activated during temporal perception (Livesey et al., 2007). Craig therefore proposed that emotional distortions to time occur when the AIC is simultaneously activated due to temporal processing and homeostatic regulation. So, when judging the duration of a highly arousing event, increased right side AIC activity as a result of increased SNS activity alters the way in which time is processed by the AIC resulting in a lengthening of time. Conversely, when judging the duration of a calming event, left side activation of the AIC from increased PSNS activity causes a slowing of perceived time. Here, arousal is a primary driver in temporal distortion.

2. *Attentional allocation and cognitive load*

Research consistently shows that the subjective speed of time is altered by changes in cognitive load (Wearden, 2015). In general, engaging and engrossing tasks with a high level of complexity are associated with the sensation of time passing more quickly than normal. Conversely, tasks with a low cognitive load and a high degree of familiarity are associated with a slowing of the passage of time. These effects are thought to reflect changes in the amount of attention paid to time (see Wearden, 2016 for discussion). When cognitive load is high, there is little spare capacity to attend to time, this results in the sensation of time passing more quickly than normal because there is a lack of temporal awareness. When cognitive load is low, attention to time is higher than normal and this creates a sensation of time passing more slowly than normal. Changes in the level of attention paid to time therefore suggest that time passes slowly during boredom because of an increase in "clock watching". The allocation of cognitive resources coupled with the importance of time in a given task, may therefore alter the subjective speed of time.

3. *Neuronal desensitization*

Hayashi and Ivry recently proposed (2020) that distortions to time may result from desensitization of duration tuned neurons following prolonged activation. Duration judgements are systematically affected by adaptation procedures (Heron et al., 2012). In duration adaptation procedures participants are repeatedly exposed to an adapting stimulus duration (e.g. 500ms) which is followed by a test stimulus duration (e.g. 200ms). Participants are then required to judge the duration of the test relative to a reference duration. These procedures produce systematic negative aftereffects: test stimuli are more likely to be judged long following exposure to a short adaptor and more likely to be judged short following a long adaptor. Although, previous neuroimaging studies suggest that these effects result from desensitization of duration tuning neurons in the supramarginal gyrus (Hayashi et al., 2015), until recently it was unclear whether this activity reflected the physical or the subjectively perceived duration of the stimulus. However, using a modified adaptation procedure in which physical duration was held constant but subjective duration varied, Hayashi and Ivry (2020) were able to demonstrate that activity in the right supramarginal gyrus reflects subjective rather than physical duration. Temporal distortions may therefore result in circumstances in which certain duration tuned neurons become fatigued, allowing neurons tuned to other (longer or shorter) durations to influence perception.

4. *Prediction error*

Recently, Toren, Aberg and Paz (2020) proposed that distortions to the passage of time may result from positive and negative prediction errors. Prediction errors refer to the error between predictive and received behavioural reward outcomes. A better outcome than predicted is referred to as a positive prediction error (PE+) and less reward or a worse outcome than expected is referred to as a negative prediction error (PE-). Toren et al., (2020) noted that PE and time perception both activate the striatal systems and are both systematically affected by dopamine levels. They therefore hypothesised that this shared neural circuitry may enable prediction errors to distort perceived duration. To test this, they conducted a series of experiments in which participants made judgments about pairs of visual stimuli A and B during fMRI scanning. The relative duration of A and B were manipulated to be short-long or long-short and the images were overlaid with a value indicating monetary gain or loss. A gain greater than expected constituted a PE+ and a loss greater than expected constituted a PE-. As hypothesized, PE's distorted time with increases and decreases in perceived duration for PE+ and PE- trials respectively. fMRI analysis confirmed that the effects appeared to be driven by striatal activity. Events which deviate markedly from expectations may therefore distort time because they induce a prediction error which in turn influences the way in which time is processed.

So, what do these theories tell us about why time has distorted during the covid-19 pandemic?

At this stage it may be difficult to say, not least because most of these models have only been tested in experiments in which participants are making judgements about very short durations, typically in the range of seconds or milliseconds. They have also only been tested in laboratory settings rather than during real world activity. How they explain distortions to the passage of hours, days and weeks is therefore somewhat speculative.

It is however clear that lockdown has had a significant impact on emotional health, with increases in social isolation, anxiety, stress and depression noted in many locked down countries (e.g. Qin, Shen, Zhao, Wang, Xie, & Yu, 2020; Peretti, Alleaume, Leger, Beck & Veger, 2020). Using Craig's (2009) homeostatic model we could therefore suppose that the emotional effects of lockdown contributed to our distortion to time. It is interesting to note however, that the UK and French studies of time experience during lockdown did not report emotional effects wholly consistent with Craig's (2009) proposal. In France, for example, stress did not mediate temporal experience but in the UK, it was a predictive factor. Similarly, depression was not a predictive factor in UK, but sadness mediated temporal experience in France. Furthermore, anxiety was not predictive of time in either territory. The effects of emotional arousal on very long epochs (days and weeks) may therefore be more subtle than described in Craig's original model.

Lockdown also resulted in significant change to the structure of daily life. For many, the absence of the office coupled with the advent of home-schooling resulted in a lifestyle which many of us are simply unaccustomed to. Such changes may have contributed to temporal distortions via a number of mechanisms. Firstly, because our activities were so different to those which we would normally perform it is possible that lockdown life contained more prediction errors than normal life. This increase in prediction errors may have distorted time in the manner described by Toren et al., (2020). However, the absence of a relationship between distortion to time and Ogden's (2020) measure of 'how much has your daily life changed as a result of covid-19' perhaps suggests that prediction errors have less capacity to distort very long durations.

The new routine imposed by lockdown may also have influenced information processing load because of increases and decreases in activity for different groups of people. Indeed, in the UK being busier was associated with a faster passage of time and in France increased boredom was associated with a slowing of time. Both of these effects can be explained by differing levels of task load and engagement influencing the amount of attention paid to time. When busy we have less capacity to monitor time and when we are bored temporal monitoring increases. Interestingly, it is also possible that attention to time was also affected by the media focus on the temporal aspects of the lockdown restrictions e.g. how long can you go out for, how long will the restrictions last for. This increased focus on the importance of time may therefore have contributed to the slowing of time experienced by many.

In conclusion, although the above theories each offer an insight into why time might distort, each theory in isolation is only able to explain some of the distortions observed. This does not mean that these theories are incorrect. Instead, their difficulty in explaining all temporal distortions is perhaps a reflection of the fact that in the complexity of the real world, temporal distortions perhaps have different underlying causes in different circumstances. To enable the development of a complete theoretical account of how and why time distorts during real world activity, it is clear that research needs to begin the journey from the lab into the real-world environment. For now, however, with a second lockdown looming, readers should focus on cultivating satisfying social relationships and a sufficient number of tasks to prevent boredom in order to ensure subjectively short future lockdowns.

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