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The Neuroscience of Classrooms

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This document reviews the proposed classroom design by Spaceoasis from a neuroscientific perspective. In particular it fulfils the following requirements:

1 Critique of initial design to inform final product & build specification

2 Detailed evaluation and commentary

The document is based on the two designs received (exhibition stand and full size classroom), which are shown in Appendix 1, and the structure of the document takes its lead from the designs. General statements from the neuroscience/psychology literature are presented, with specific callouts relating to each design feature.

Short references are given in line with the detailed reference list provided at the end of the document.

The information contained within this review was collated, and is correct to the best interpretation of the requirements, as of 16th December 2016.

Introduction

This design review was commissioned as a result of a segment on the neuroscience of retail design which formed part of BBC Radio 4 Design Dimension series. Traditionally the goals of classroom design have differed from those of retail design, after all classroom design should facilitate learning whereas retail spaces aim to optimise sales. But what if we were to start thinking of the students as consumers of their education and the learning to be the product we want to sell? Immediately the methods used by retail designers that use environmental effects and particularly sensual cues to influence the mental states of shoppers become relevant to classroom design. For some time now, retailers have been leveraging ideas from neuroscience and psychology to effect behavioural change and in this document I will highlight where those learnings are directly applicable to the design of education spaces, and in particular how they relate to designs proposed by Spaceoasis (Appendix 1).

Before evaluating the designs, it is worth introducing a few key concepts from the neuroscience literature that underpin much of the commentary.

Sensation, Perception & Attention

The process of sensing the environment, be it through the eyes, ears or nose is the start of a complex journey within the brain. All senses, and there are actually more than the five they typically taught in schools, are processed in distinct regions of the cerebral cortex. Although these regions are separate, they are also highly connected, meaning that any one sense can affect the way another sense is interpreted. This interpretation, or perception, results in our conscious awareness of the sensory input and is, in fact, only minimally the result of the raw sensory information. Perception is created in the brain and is highly subject to prior learning; we perceive what we expect to sense rather than what we actually sense.

As if that isn't bad enough, our brains have to filter a lot of what we sense, otherwise we would be completely overwhelmed with the amount of information being received. This filtering is called attention, and once again can be influenced by sensory signals and also prior learning, expectation or motivation. For example our attention might pulled by someone entering a room, but will return to the task it was previously engaged in, watching TV for example, if we deem it more important or of greater interest than the person who just entered. The upshot of this is that we will tend to miss things which are unexpected unless they are salient enough to capture our attention, and if they do then we're certainly going to miss other signals that were available at the same time. Attention is a finite resource and to a certain degree is ring-fenced to modality (sense), meaning we can't completely turn off our hearing to increase our visual attention for example. This explains in part classic results like the Cocktail Party effect where our attention will be

redirected on hearing a salient word like our name even when we're already engaged in a conversation in a noisy room.

Attention is the gateway to long-term memory, and can be manipulated. This is something that is well understood by retailers who use visual standout to direct attention to products on shelves, to ensure that messaging on packs is easily readable and even to alter behaviour through sound and scent which have become associated with emotional responses, such as the fresh baked bread smell piped into the car parks by Costco – it's a homely smell which triggers a positive emotional response in the shopper and happy shoppers spend more.

System 1 and System 2 Thinking

These effects of prior experience are incredibly strong, and their ability to effect, or nudge, behaviour have only recently been understood and applied in areas like health (donor programmes), financial planning (military pension programme) and education. Following a lead from the UK Government's Behavioural Insights (Nudge) Team, US President Obama set up the Whitehouse Social and Behavioural Sciences Team in 2015. These units apply learnings from neuroscience and psychology which focus on the cognitive biases influencing unconscious behaviour identified most notably in the work of Daniel Kahneman and Amos Tversky.

In a series of studies, Kahneman and Tversky identified that we are unaware of much of the decision making and behaviour we exhibit on a daily basis. These unconscious processes are the result of a deliberate strategy by the brain to automate responses to relatively predictable events (System 1) to free up resources for new learning and problem solving (System 2). System 1 functions quickly because it uses heuristics, or probability models, laid down in the brain over time that will always favour the response which has proven to be most correct in the past. Consequently, System 1 is irrational because it does not consider all possible outcomes and is particularly bad at coping with the unknown or unexpected. System 1 has a tendency to trigger behaviours before all the necessary information is available and this impulsivity means it is strongly influenced by the emotions associated with our prior experiences. Retailers rely on creating positive experiences in their stores to ensure that positive emotions are associated with all memories of that environment, which in turn increase the likelihood of preferential selection of that retailer when faced by the array of alternatives in a mall or on a high street.

System 2 functions much more slowly because it is optimised to evaluate all relevant information and make a rational decision. It is engaged when new situations or environments are encountered, or when a System 1 triggered behaviour/response results in a consciously detectable error, in which case the heuristic, or cognitive bias, that resulted in the incorrect behaviour needs to be adapted with the new information. System 2 always operates at a conscious level and if we were to use this system all the time our ability to interact with the world would be significantly

impaired. Just as attention acts as a filter on the inputs to the brain, System 1 acts as filter on the outputs from the brain, freeing up the slower more costly System 2 resources to be used only when necessary. Retailers typically try to keep shoppers on autopilot, only engaging System 2 when they need to communicate about new products or innovations, and always with a view to these becoming encoded in memory to begin to influence System 1 thinking. This is because System 1 decision making is highly predictable and presents the opportunity for manipulation by the retailer.

Perhaps the easiest way to understand the interaction between System 1 and 2 is by an example. When we first learn to drive a car we are slow and very prone to errors like selecting the wrong gear, stalling the engine or not looking in the rear-view mirror before pulling out. System 2 is heavily engaged at this time while we lay down the processes that will ultimately become second nature for any regular driver. At this stage we struggle to react quickly to unexpected events we encounter along the journey such as another driver's erratic braking or a pedestrian who crosses in front of us, and this is because we are still consciously focussed on every gear change and every manoeuvre. As we become more proficient, driving seems to get easier and we get better at handling the unexpected. This is because changing gears based on the sound of the engine and looking in the mirrors becomes automated and unconsciously handled by System 1 freeing up more resources for dealing with those unusual events. Established drivers often report having driven for 10-20 minutes without having any recall for the journey, and this is because System 1 was handling almost every aspect of the driving, freeing up the driver to listen to a podcast, plan a shopping list or talk to other passengers in the car.

Memory

By now it should be clear that memory is the key to System 1 behaviour, and this is why so much focus is placed on the manipulation of attention by retailers. For stimuli to be associated with a behavioural or emotional response they need to be attended to in the first place. Attentional filters mean that short-term memory is finite and simple studies looking at the ability to recall strings of letters or numbers have confirmed this. Long-term memory is believed to be potentially infinite and it is this part of memory that System 2 updates (encodes) and which ultimately influences System 1. The heuristics that drive System 1 can be thought of as short-cuts that represent a whole set of related long-term memories but are clearly dependent on the availability (recall) of those memories in the first place. Individual memories are connected in a vast network and related memories activate connected memories and this is why behaviours can sometimes be triggered by related but inappropriate memories because one of the most influential biases is the availability heuristic which triggers decision making based on the easiest, fastest, most readily available information, which includes our memories. Consequently the more salient or emotionally resonant a memory, the more readily it is recalled and the greater it's potential for influencing

behaviour. Memories associated with positive emotional responses tend to be recalled faster and so there is great value to be had from exploiting this with respect to educational spaces just as retailers have been doing for years.

So as we can see, brands and retailers use the predictability of much human decision making to trigger desirable behaviours. There are some who would view this as a little sinister and certainly manipulative, especially when the true beneficiary is a business. By viewing students as consumers who sometimes want, but sometimes need to be encouraged to want, to buy the education product, we can apply this same thinking in a way the benefits both teachers and students.

Design Review

The two classroom designed proposed by Spaceoasis feature a number of common elements:

- Group gathering space - theatre style seating with storage and a blank rear wall that can be used for projection
- Collaboration spaces:
- Formal in the full classroom design - bench seating and rectangular table
- Adaptive in both designs - round tables and stools
- Contemplation space – screened off area with more informal (stone cushion) seating
- Digital space – bar style with high seats
- Storage space – for unused furniture

In addition the classroom design for the show stand includes a Maker Space for building and experimentation with stools and a workbench, whilst the full size classroom includes a moveable smart screen and a teacher's side table.

In this section of the document I will review each element in turn and then end with some more general statements about the overall effect from the flexibility and aesthetic qualities of the space.

Group Gathering Space

When teaching to a class it is common to have periods of information delivery when it is important that the whole class attend to a single speaker. As discussed in the introduction, attention is a finite resource and for this reason a "spotlight" metaphor is frequently used to describe the allocation of attention since we tend to focus it on a single subject of interest or of most relevance to us at any moment in time. Traditional classroom design has students sitting behind of rows of desks, all of which are at the same level, meaning that the view of the speaker gets progressively worse the further back you are. Research that stems from the work of Khaneman & Tversky is clear, our biases lead us down the path of least resistance, which means if you want attention to be focussed on a speaker, it needs to be easy for the class to do so. The banked seating in these designs provides clear lines of sight for all students making it easy for them to attend to the teacher as a result of improved visibility and audibility. Moreover it makes it easy for the teacher to see every student and so able to monitor the class response to the content better: confusion or misunderstanding will be easier to detect, questions will not be missed and engagement through the reflexive attention to faces we develop as infants will be exploited to the max providing immediate feedback on the comprehension of the lesson.

Attention that is not held will wander. This is because the default mode network, which is responsible for brain activity when not engaged will take over. This puts the brain into a state of readiness and highly receptive to reflexive System 1 based processing. What this means is

that the attention can be easily diverted from the intended focal point and so it is important to remove possible distractors, and especially mobile devices, from the immediately visible environment. At school age "belonging" and "validation" are a hugely important and account for much of the success of social networks with teenagers, so parting with mobile phones even for an hour or two can be quite emotionally disruptive. The storage space under the seating means students will be able to remain close to personal effects, without them being in sight where they will inevitably act as a salient distraction. Physical discomfort can also act as distraction, and the addition of seat cushions serves two functions: it allows the students to maximise their comfort when sitting in this space during delivered content, but more importantly it involves them in the physical design of the space every time they sit down which has been shown to increase engagement.

Our brain tends to group items by proximity and desks can act as boundaries, or barriers, to that process, restricting the ability for the students to see themselves as part of the whole class and the teacher as part of it too. In classes with desks, students tend to choose the same spot every time they enter a room which restricts social interaction and can encourage the formation of cliques. Removal of desk barriers in this shared space will bring the class together to enhance discussion and shared learning. It will be easy for students to become part of the learning experience by stepping to the front and sharing results with the rest of the class and seeing how others respond. As students prepare for the future, communication and public speaking skills are being increasingly valued by employers and this design will facilitate the development of such skills in addition to improving the quality of learning.

The clear wall behind the seating offers a unique opportunity to change the look and feel of the space through decoration, lighting or projection. Whilst this is clearly sub-optimal for presentation to theatre style seating, it presents an opportunity to make the learning space more immersive. The imagery we are surrounded by at the time of learning becomes linked to the learning in memory, helping to anchor concepts and facilitate recall. More importantly, if there's one thing we know from retail, it is that you need to make a space interesting to draw shoppers in and you need to keep refreshing it to bring consumers back. Even something as simple as a written quotation or question can become part of the ritual to get students thinking and talking while the class is still assembling. This gives students a chance to begin idea formation ahead of teaching which will promote question asking in class. The flexibility of a wall like this also allows the students to contribute to look and feel of their own space even if the classroom is used by different classes at different times since digital images, including class generated content, are easy to store and replace to match the class in residence. This in turn will ensure that the environment can always be relevant to class being taught, and will further help to provide a bond between the students and the environment they learn in.

Collaboration spaces

Albert Bandura's Social Learning Theory suggests that learning is not simply a passive process in which the student absorbs information from a teacher, but rather is active and social occurring as a result of observation and modelling. This theory shares ideas with similar developmental theories which emphasise the role of play in learning. More recent neuroscience research has identified the presence of mirror neurons which appear to be the mechanism by which the brain can learn vicariously through the observation of others by modelling or representing the behaviour internally. The design of the collaboration space allows for both physical and cognitive collaboration by being a highly flexible learning space with easily reconfigured seating allowing students to learn alongside each other and from each other

The importance of spaces which develop communication skills has already been mentioned, and this space facilitates more intimate conversation and demonstration skills. Two types of collaboration space are represented in these designs, the formal rectangular table with bench seating and the more flexible round tables and stools. Together they provide teachers with ability to impose more or less structure on a collaborative session, with the table being ideal for more focussed, maybe facilitated group work where an entire group is to learn together, whereas the round tables are more suited to multiple smaller groups and less structured sessions.

The surface of the tables can be written on to allow shared ideas to develop between the students sitting around them. Research shows that visual communication and in particular the ability to explain ideas through pictures and diagrams (sketching/scribing) facilitates learning because it strengthens the neuronal pathways in the brain, providing additional routes to enable recall from long-term memory. Retailers and advertisers have long known that pictures and iconography are processed faster than words leading to faster more accurate recall of information. The shared nature of these drawing surfaces, and scalable size through the addition of more round tables, creates a large and flexible canvas that can develop with the ideas of the group, rather than constraining them to a single fixed size whiteboard for example.

As has already been mentioned, research shows that people are more invested in environments they create, and once again, the flexibility of the seating and table arrangement will allow students to create personalised learning spaces for the whole class or groups they are working in.

Contemplation space

As mentioned in the introduction, attention is both finite and ring fenced. This ring fencing means that cross modal interference is unavoidable, in other words it is virtually impossible to suppress auditory processing whilst reading, drawing or building. Intuitively this might seem to provide an opportunity for multi-sensory teaching which increases the

number of sensory pathways to long-term memory, and that is true. But this inability to suppress auditory input can be damaging to attention, since it makes it difficult to suppress distractions. A quieter space for reading, thinking and even potentially meditating can improve concentration by simply making it easier – if the brain can't suppress all inputs, and evolution has ensured that it can't with good reason, we sometimes have to give it a helping hand. Recent research has shown the productivity in open offices is significantly damaged by noise pollution from other workers, not only because of increased distraction, but also the accompanying stress of not being able to concentrate. There is some truth to the phrase "can't hear myself think" because the inner voice that we are referring to when we think or read activates the same brain regions as speech and hearing, meaning that it is in direct competition for attention.

Reflection is also an important part of memory consolidation, since it invokes a process known as rehearsal, which is simply the repeating or re-imagining of information and experiences. Rehearsal is known to be a significant aid to memory since it strengthens neuronal pathways. It has recently been suggested that the some of the memory loss in Alzheimer's disease can be recovered through rehearsal strategies and so a space to practice this in is essential to long lasting learning.

Another technique for improving productivity, learning and memory consolidation which is rapidly garnering significant empirical support from psychology and neuroscience is mindfulness, which is the process of being fully engaged with the activity you are doing. If this sounds like "concentration" then that's not really surprising, since the two are highly related. Concentration relies on the ability to suppress external distractions as much as possible, and the mindfulness literature suggests that this can be improved with practice. Many techniques for this exist with guided meditation being the most common because it is all about training the brain to focus and suppress external distractions and dismiss those that cannot be suppressed. The softer lines of this space with its curved edges and softer seating facilitate relaxation and deaden sound. So, whilst it might be a little too progressive to suggest that the contemplation space be used for mindfulness training, it is a space that would enable students to feel the benefits associated with this.

The contemplation space also serves as a quiet, more private space for pastoral care. As has already been suggested, one of the greatest barriers to fast recall of information is negative emotional experiences. The inevitable truth of social interactions and collaborative learning between students is that there will be conflict and tension at times. This space allows the teacher to create a safe environment in which to resolve conflict and talk to students away from the rest of the class, thus improving the emotional wellbeing of the students.

Digital space / Maker space

The two areas of the classroom design that perhaps lend themselves most to retail like design thinking are the digital and maker spaces. These spaces take their cues from established retail design principles: brick, wood and metal work for the maker space and a much cleaner simpler design for the digital space reminiscent of Apple and mobile phone stores.

Students will instinctively pick up on these cues as a result of priming from other environments they have encountered. The clean lines of the digital space will facilitate focussed research, whilst the bar like design still supports easy collaboration between adjacent workstations. The workshop aesthetic of the maker space will prime the students, through associative memory, and encourage more exploratory and potentially creative behaviour than is likely to be seen in the more research focussed digital space, since the materials used give students permission to be less precise. The natural imperfections in the materials will prime students to focus less on perfection and precision, and to be more innovative in their approach to experimentation and reinforce a general principle from scientific research which is that problem solving requires the making of mistakes.

Storage space

Apart from the sheer practicality of having somewhere to put stuff, and especially freestanding furniture which is not in use, the storage space serves an important function in enabling decluttering of the environment. This is important for a couple of reasons: it creates space and removes visual noise.

The creation of space is important because it facilitates movement within the classroom. The fuel of the brain is oxygen. When students are stationary the heart beats less and the flow of fresh oxygen to the brain is reduced. By creating space for movement, either in the form of deliberate physical activities designed to energise the students, or more simply by allowing small groups to spread out and increase movement between the groups to require standing and walking, the classroom designs facilitate fatigue reduction and improve cognitive performance.

Just as auditory noise can distract attention, visual noise can do this too. In a classroom setting visual noise can be in the form of irrelevant or outdated wall decorations, outdoor activities seen through a window or irrelevant and inappropriate furniture and apparatus in the room itself. For example, having a TV in the classroom when it is not being used is a System 1 primed reminder of what a lot of students might rather be doing! By removing, or at least minimising visual noise, the visual system is freed up to concentrate on what's relevant or important making it easier for students to focus on the task at hand. Again, it is worth remembering here, that the best way to nudge the behaviour you want is to make it easy.

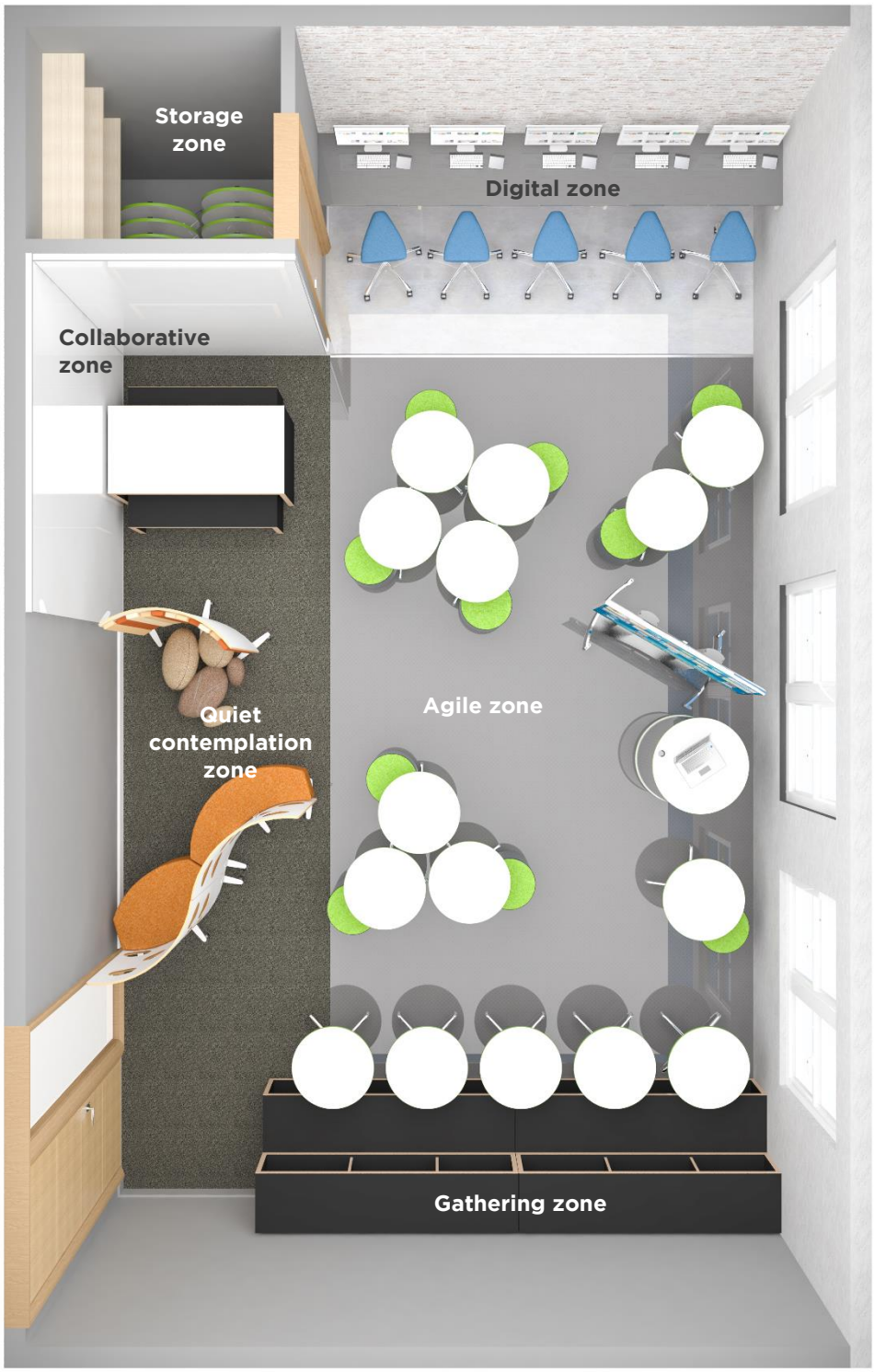
General Aesthetic

When Starbucks began its worldwide domination of the coffee shop market, and in fact pretty much created the coffee shop market we know today, they adopted a guiding a principle, and that was to be everyone's third space. The third space concept originates with Ray Oldenburg and relates to a space that is neither home (1st space) nor work (2nd space). It is the space where people seek refuge from the other two places and so they come to it for pleasure, relaxation and physical and mental rejuvenation. For Starbucks it was essential to create an environment that had all the warmth and informality of a worn living room sofa, and yet was a place where people would meet, think, write or chill. They were astoundingly successful, of course, and customer loyalty followed.

The classroom is the 2nd space for students, and as such it cannot go as far as Starbucks did in mimicking the comfortable trappings of home, because the environment needs to communicate to the students that they are there to work. But that doesn't mean it should adhere to a traditional "institutional aesthetic", because research shows that we are hard wired to respond to good design and might even seek it out to experience a release of pleasure enhancing neuro-chemicals (opioids and dopamine) in the brain. If a classroom is visually appealing, students will want to be inside and will want to come back.

The designs proposed communicate good design for all the reasons already discussed, and moreover through a consistent look and feel that, whilst creating distinct zones to support different learning experiences, presents a harmonious gestalt (whole). The zones naturally delineate without the use of walls or barriers, each having its own identity which will anchor the learning in long-term memory and prime behaviour appropriate to the space. The ability to declutter the environment will the use of colour, shape and materials to be processed unconsciously as System 1 immediately triggers the positive emotional responses. As such the classroom designs are not just a place to deliver learning, but they become a tool that can be incorporated in lesson planning and used to improve the education experience for both the students AND the teachers.

Appendix



MakerSpace (shared with other classrooms)

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After graduating in Mathematics (Sheffield University, UK), Tim travelled the world as a software developer living and working in the US, Asia and Switzerland. He returned to university in 2005 to study Psychology and completed his PhD in visual neuroscience, decision making and aesthetic perception at Royal Holloway, University of London in 2010, where he continues to research and teach.

In 2011 he co-founded Acuity Intelligence Ltd, which defines itself as a research company grounded on scientific principles, which specializes in real-world applications of eye-tracking, bio-metrics and cognitive neuroscience. In the past 5 years, as Technical Director, he has headed-up all research and development within the company and has worked with companies as diverse as P&G, Coca-Cola, Unilever, GSK, Ralph Lauren, BskyB, The Guardian and the Walt Disney Company to evaluate and optimize digital media, package designs, mobile apps and marketing strategy.

As an educator Tim has developed and implemented neuroscience programs for a range of academic and commercial customers. He recently contributed to BBC Radio 4's Design Dimension, has appeared on a number of TV shows including Channel 4's The Secret Life of Buildings, C4's Embarrassing Bodies and BBC1's Secrets of the Sales and was scientific adviser for the 2015 Toyota Tacoma "Sal a Jugar: Fun Games" advertising campaign

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