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Why Evolutionary Mismatches Are Ubiquitous While Evolutionary Matches Are Rare When Humans Use Technology

Jose C. Yong[1] and Satoshi Kanazawa[2]

[1] School of Social and Health Sciences, James Cook University
[2] Department of Management, London School of Economics and Political Science

Evolutionary mismatch caused by environmental changes from the use of cultural and technological solutions is a well-established and extensively studied area. Despite the well-intended purpose of developing technologies to align the environment with and thus meet our adaptive needs, it is interesting that evolutionary matches—the natural conceptual counterpart to evolutionary mismatch—are seldom mentioned, whereas mismatches are discussed in abundance. We offer a definition of evolutionary match and propose several reasons why matches in the long run are unlikely given an extended period of technological consumption and reliance. Specifically, technologies embedded in culture lead to problems of an oversupply of solutions, as well as hyperstimulation and hypostimulation of evolved human adaptations, all of which drive the creation of more novel remedies to deal with these new problems in a never-ending cycle. Possible solutions to the inherent and inevitable problems of using culture and technology to satisfy our needs are proposed, in addition to discussing whether new technologies provide much evolutionary match at all as we move toward the future.

Public Significance Statement
This article advances several explanations for why the use of cultural and technological solutions in humans, while capable of addressing adaptive problems initially, inevitably leads to more problems in the long run which necessitates the use of more technology to further resolve. How we may mitigate problems that arise from technological consumption is proposed.

Keywords: evolutionary mismatch, evolutionary match, technology, hyperstimulation, hypostimulation

Since Ernst Mayr (1942) suggested that genetically uniform populations highly adapted for specific ecological conditions are vulnerable to extinction from sudden environmental changes, researchers have extensively studied how organisms become mismatched to their habitat, leading to maladaptive outcomes (Anderson et al., 2010; Gross, 1955; Visser et al., 2012). Evolutionary social scientists have also relied on evolutionary mismatch to understand psychological, behavioral, and health problems in humans. For example, humans evolved to like sweet- and fatty-tasting things to motivate the search for calorie-rich foods in nutritionally scarce ancestral environments. However, this preference is hijacked by modern food companies that mass produce consumables containing large amounts of sugar and calories, resulting in health issues like obesity and diabetes (Gluckman & Hanson, 2006; Popkin et al., 2012). Other research has also indicated that our tribal origins, whereby ancestral humans evolved to live in kin-based groups of up to approximately 150 individuals (Dunbar, 1993), may be responsible for contemporary problems of alienation and loneliness in cities populated by hundreds of thousands of strangers (Kavanagh & Kahl, 2018; P. Li & Kanazawa, 2016). Similarly, the evolutionarily

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Jose C. Yong https://orcid.org/0000-0002-6413-2016
Correspondence concerning this article should be addressed to Jose C. Yong, School of Social and Health Sciences, James Cook University, 149 Sims Drive, Singapore 387380, Singapore. Email: jose.yong@yahoo.com

novel levels of competitive stress and status anxiety in modern, capitalistic societies have been identified as a factor underlying disinterest in mating and ultralow fertility today (Yong et al., 2024).

Evolutionary mismatch has emerged as an important framework to understand the impact of cultural inventions and technological use on humans (e.g., Brooks, 2021; N. P. Li et al., 2018; van Vugt et al., 2024). Technology, broadly conceived, refers to the use of new methods, materials, and devices to solve practical problems or accomplish tasks (Hinsz, 2015). While technologies may sometimes be created for frivolous purposes (e.g., panini makers, computers that can differentiate chocolate chip cookies from oatmeal raisin ones), the axiom that "necessity is the mother of invention" implies that a large majority of technologies arise from serious unmet needs. Cultural practices (e.g., mating rituals, kinship systems, social norms) also function as a form of technology when they help to support the pursuit of survival and reproductive goals (Yong & Li, 2022). Our intelligence enables us to analyze problems and devise highly fine-tuned and effective solutions using technological tools, cultural practices, or both, thus allowing the brutal and unforgiving selection processes that underlie natural adaptation to be sidestepped. In other words, whereas adaptation for other species occurs when the unfit die out while only the fit propagate, we seek to adapt the environment to us rather than adapt ourselves to the environment (Ehrlich & Ehrlich, 2008). While survivability is improved through the creation and use of technologies, they become deeply embedded in human lifestyles through culture (Boyd et al., 2013). Over time, the increasing reliance on cultural and technological solutions produces misalignments between our once-adaptive traits and the increasingly technologically dense cultural environment.

For instance, modern medicine and hygiene practices eradicated several microbes that helped to regulate the immune systems of early humans, making modern humans more susceptible to hyperinflammatory conditions including multiple sclerosis and irritable bowel disease if those medicines or hygiene behaviors are not adopted (Fleming, 2011; Parker & Ollerton, 2013). Computers and digital technologies improve productivity, efficiency, and flexibility in modern organizations, but increases in virtual work and remote interactions pull people further away from physical work and face-to-face interactions which are vital to humans leading fulfilling lives (van Vugt et al., 2024). Evolutionary mismatch is therefore a useful perspective to understand problems that result from technological penetration and cultural change.

The natural conceptual counterpart to evolutionary mismatch is evolutionary match, where an evolutionarily novel environment aligns with our evolved adaptations (Raubenheimer et al., 2012). However, little has been written about evolutionary matches in the human psychobehavioral space. Although the introduction of a new technology typically involves an evolutionary match whereby the technology aligns with the adaptive need at first (see van Vugt et al., 2024 for some examples), much if not all of the available literature focuses on mismatch. In this article, we introduce and establish the concept of evolutionary match and argue that, for at least three different reasons where prolonged technological use is concerned, it is unlikely to exist frequently, if ever, while evolutionary mismatches are abundant and ubiquitous.

Evolutionary Match

Evolutionary mismatch occurs when a new environment causes an adaptation to no longer be adaptive (Riggs, 1993). As a starting point based on this definition of mismatch, an evolutionary match may be understood as a situation where an adaptation is still adaptive despite changes in the environment. However, the new environment merely continuing to allow the initial adaptive problem to be solved is an insufficient basis for match. For instance, overweight or diabetic individuals who overconsume candy and chocolates from the supermarket have food to eat and are not starving to death, so supermarkets solve the original adaptive problem of procuring food. Nevertheless, the supermarket is a mismatch rather than a match because it allows for overconsumption of unhealthy snacks and creates new health problems. Therefore, a more comprehensive definition of evolutionary match should also include solving an adaptive problem without creating new problems. More specifically, we suggest that evolutionary match refers to situations where environmental change, such as through culture or the use of a technological invention, solves an adaptive problem that could not be solved otherwise and yet does not

create another problem that did not exist before the change or invention.

Nonhuman examples of evolutionary match can be illustrated through animals that significantly alter their environments to meet survival needs without incurring new problems and, in some cases, even help to balance or enhance the overall ecosystem as a byproduct. For instance, beavers build dams, termites build mounds, and kangaroo rats create extensive underground burrows to protect against weather and predators, store food, and regulate environmental conditions (e.g., ventilation and temperature management systems; Holtmeier, 2015). We would speculate that these creatures are unlikely to be getting too unhealthy by consuming more than they should or staying indoors too much, because any self-imposed environmental modifications (e.g., changes in ambient temperature or availability of food) would have been very gradual, not sudden as frequently happens when humans introduce new technology to their environment. Termites, for example, are highly adapted for life in mounds as they evolved a caste system of workers, soldiers, and reproductives to facilitate division of labor and are allocated specific positions within the residential space to maintain the functions of the colony (Korb & Thorne, 2017). Moreover, the dam-building activities of beavers cultivate wetlands that can improve surrounding water quality and enhance biodiversity (Brazier et al., 2021), while the large termite mounds enhance soil composition and nutrient cycling (Korb & Thorne, 2017). The tunneling activities of termites and prairie dogs also aerate the soil, benefit plant growth, and create habitats for other species (Holtmeier, 2015; Korb & Thorne, 2017). Natural ecosystems tend to be self-sustaining insofar as species evolve alongside one another and with their habitats at a tolerable pace (Chapin et al., 1996).

In humans, a hypothetical example of an evolutionary match is perhaps the original precursor of a house that shielded ancestral humans from the elements and predators so that they could stay safe and, as a result, live longer. But as we will explain in greater detail in the next section, such human examples are necessarily hypothetical because there appear to be no clear cases of evolutionary match where technology is involved for a long enough period of time. A wide array of mismatches ranging from diurnal sleep disruptions to carcinogenic diseases can be traced back to the moment ancient humans harnessed one of the earliest forms of technology—fire. As for our hypothetical housing example, it has been the case that houses eventually became too warm and cozy; humans then invented a couch, a TV to place in front of the couch in the house, and finally a remote control so that there is no need to even get up from the couch to change the channel. Now people have become couch potatoes, leading to a variety of health risks associated with insufficient physical and outdoor activity, and the whole living arrangement is a mismatch.

Reasons That Evolutionary Matches From Technology Use Are Rare

To be clear, the current article will focus mainly on significant technologies, or those that are highly impactful, lifestyle defining, and deeply entrenched in human culture such that they have become somewhat indispensable. Examples of such technologies would include microwaves, medicines, cars, computers, and artificial intelligence rather than, say, nail clippers or mugs, because it is after all the significant ones we are most concerned about as we ponder their impact on humanity. Simple technologies like nail clippers also tend not to lead to significant problems of mismatch because the adaptive problems they were originally designed to solve would likely be quite trivial. Nevertheless, many complex technologies are the result of design iterations of simpler versions, whose subsequently far more advanced versions were unforeseen at the time of their initial conception. For instance, one of the earliest tools used by humans is the flint stone, which was used for cutting, stabbing, making other tools, and starting fires (Norton, 2021). The evolution of technology can be plotted from the flint's humble prehistoric beginnings to medieval engineering and machinery, which then provided the foundations for modern electrical and digital inventions.

The evolutionary significance of technology is rooted in how it enables users to increasingly expand their capacities, first by augmenting physical labor (simple tools), next by eliminating the need for physical effort and allowing users to focus on functional control (machines), and lastly freeing users from needing to exert control (automation; Bloomfield, 1993). The significance of a

Table 1
Summary of Mechanisms Underlying the Forward Trajectory and Prevalence of Technological Use in Humans

Why has technology flourished and is unstoppable?
• Like any other organisms, humans strive to survive, avoid death, and reproduce.
• Humans have intelligence which they use to analyze adaptive problems and develop solutions that can help them survive and reproduce better.
• Humans create technologies, which are desirable because they provide fine-tuned solutions, enable humans to expand their capacities, and allow them to adapt the environment to suit their needs while avoiding death and suffering. The initial stage is an evolutionary match.
• Over time, new problems due to misalignments between once-adaptive traits and the rapidly changing environment wrought by technology, or evolutionary mismatches, emerge.
• Evolutionary mismatches arise from hyperstimulation and hypostimulation caused by technological use, as well as oversupply of technological solutions (e.g., liberal ideals aiming to give everyone access to fitness-enhancing technological resources, consumer business strategies encouraging mass consumption of technology).
• These new problems invite further introductions of technology to deal with, which then produce more evolutionary mismatches.

given technology can also be measured in terms of how many lives it saves or how effectively it extends human life and health. The cultural environment correspondingly evolves to accommodate the growing use of technologies that enable people to reduce the need for more rudimentary forms of effort, lead safer lives, and address various adaptive needs (Boyd et al., 2013; Jordan, 2014). We argue that evolutionary matches are rare because this inevitable technological and cultural trajectory leads to new problems in at least three ways, which then require yet more inventions to resolve in a never-ending cycle (Table 1).

Oversupply

With culture and technology among the resources available to cope with adaptive problems, humans can greatly increase the odds of survival and reproductive success without having to undergo natural but slower selection processes which often involve suffering and death. Indeed, the success of technology has made survival and life easier and enabled humans to pursue the liberal doctrine that life is sacred (Clarke, 2023; Moore, 1991), which is itself a cultural invention aimed at avoiding death and reducing suffering. The sanctity of human life is emphasized in relatively recent religious teachings that regard the taking of one's life or another's as sin, as well as codified in laws that elevate life to a fundamental right (Previn, 1995; Ramcharan, 1983). This prohuman life stance has led cultural and technological solutions to be aimed at the most vulnerable or least capable individuals in the group, which then creates an abundance or oversupply of solutions and remedies for the vast majority of people. A similar liberal norm that has trended more recently is the shift toward diversity, inclusivity, and equity ideals which strives to give everyone equal access to opportunities and resources (Zhao, 2023). As we will illustrate next, oversupply is inevitable as a hierarchy of capabilities and needs exists among people. In this sense, evolutionary mismatch may be inherently built into any cultural solution to adaptive problems because technology and its success contain their own "demise" in becoming mismatches.

Building on our food-related example, given the natural hierarchy of hunting talents in ancestral hunter-gatherer groups, some hunters were always more capable of procuring food than others, and the food supply was always precarious for most. To solve this adaptive problem, humans invented horticulture, animal husbandry, and agriculture in order to create more reliable food sources and address the problem of food shortage. This has led to other technologies, such as food storage and meat curing to allow storage and accumulation of food, as well as division of labor so that not all individuals had to engage in food procurement most of the time (Ingold, 1983). As a result, today we have supermarkets where abundant food is available at reasonable costs to all, allowing everyone to meet their basic nutritional needs. But the same supermarkets have led to overconsumption of sweet, fatty, and overprocessed food, which now leads to obesity, diabetes, and other health problems.

Even today, some people—expert hunters, horticulturalists, farmers—can procure their own food and do not need to rely on supermarkets. However, most of us cannot and need the supermarkets to procure food to satisfy our nutritional needs. Our food supply chain, from ranchers and farmers to food production companies

and factories all the way to supermarkets, is designed so that those of us who are least capable of procuring food can still meet our basic dietary requirements. If all the supermarkets disappeared today, some of us could still survive, but most of us would not. As a result, we produce sufficient food, make it sufficiently easy to access for the least capable members of society, and in the process end up producing too much for the average members of society.

To further illustrate this point, another case of supply imbalances resulting from catering to everybody is the internet as a voice platform. Until the birth of the internet, people had to be vetted and approved by gatekeepers (e.g., book editors, publishers) to spread their ideas in writing. As such, only trusted experts could publish books on topics they had proven themselves to be knowledgeable about. Going further back in time, people only listened to recognized experts (e.g., village elders about political matters, the best warriors about fighting, the best hunters about hunting), but with the internet, anyone can have a blog or a Twitter/X account and share opinions about any topic, even if they have little knowledge on them. Yet another example can be demonstrated from the invention and use of mobile phones. During premodern periods, only very important individuals could get everyone's attention. Kings and emperors could always summon doctors to attend to their health problems, while commoners died of diseases without receiving any medical attention. Today, anyone can call from anywhere to get an ambulance. Similarly, in earlier eras, only kings and diplomats knew what was going on in other countries, but now anyone can check the latest world news on their phone. These evolutionarily novel developments likewise have their own problematic outcomes, such as difficulties with discerning the usefulness of information, the growth of aging populations, and fractures in public opinions on sociopolitical affairs.

The oversupply of solutions today also extends beyond those for lower level survival needs like food and health to include higher level ones like esteem and social status (Maslow, 1958). As modern cities with evolutionarily novel levels of crowdedness and social inequality increase people's perceptions of competitive stress and concerns about social status (Yong et al., 2024), a substantial part of modern consumer business strategy is aimed at exploiting people's evolved tendency to want to achieve status and social opportunities as quickly and with as little effort as possible (Kasser et al., 2004). Similar to being able to freely post opinions on online forums, people can now utilize social media platforms to advertise status without having to overcome the obstacles needed to earn that status. For instance, it is not uncommon for social influencers to borrow a luxury car or rent a studio mimicking the interior of a private jet to produce status-signaling content for their Instagram or TikTok profiles (Lim, 2023). On the one hand, this drives ever-increasing levels of status anxiety as everyone seems to have status and people feel more pressured to keep up through garnering likes and followers, materialism, and wealth displays (Yong et al., 2024); on the other hand, it is becoming harder to determine who truly has status, which motivates ever more novel and creative ways to exhibit it, such as by deliberately dressing poorly (Patrick, 2024) or buying an art piece made up of a banana duct-taped to a wall for US$6.2 million and then eating it (The Business Times, 2024), in turn making status even more elusive. In sum, highlighting the problem of oversupply affords a perspective to better understand and forecast its consequences.

Hyperstimulation

The presence of the technological solution can excessively trigger the adaptation, leading to overconsumption of the solution. This effect has been described as a form of hyperstimulation from exposure to a supernormal stimulus—an exaggerated version of a stimulus to which there is an existing response tendency, or a stimulus that elicits a response more strongly than the stimulus for which the response evolved (Barrett, 2010). Cuckoo birds use such stimuli to avoid parental care at the expense of reed warblers and other host birds (Grim & Honza, 2001; Holen et al., 2001). Cuckoos lay eggs that mimic the color and pattern of eggs in the host bird's nest, but they are usually larger and more noticeable. This larger size acts as a supernormal stimulus because it causes the host bird to perceive the cuckoo egg as healthier or more viable despite looking different from its own eggs. Cuckoo chicks hatch earlier than the host's chicks and have a very loud and persistent begging call, which also acts as a supernormal stimulus by

causing the host bird to prioritize feeding the cuckoo chick over their own chicks. In addition, the brightly colored and patterned mouths of the cuckoo chick can hijack the host parents' instincts to respond to visual cues suggesting an urgent need for food and trigger a stronger feeding response from the host parents.

Modern human contexts possess numerous instances of hyperstimulation from supernormal stimuli. One common example is hyperpalatable foods (e.g., junk food), which are designed to be as tasty as possible but contain low nutritional value or unhealthy chemicals (e.g., artificial flavoring). As frustrated parents would know, introducing hyperpalatable foods to children makes them prefer such foods over healthier ones (Cornwell et al., 2021). Such problems arise because of a process described by adaptation-level theory (Edwards, 2018; Helson, 1964), whereby people evaluate a stimulus relative to a neutral level from past experience. This neutral level (also referred to as the "adaptation" level) serves as a reference point against which new stimuli are compared, and aspirations for a reward in a certain category are soon reset to the highest level of reward experienced in that category. As a consequence, hyperstimulating cues cause people to prefer the artificially enhanced version of what would otherwise be the natural stimulus. In ancestral environments devoid of the hyperstimulation of modern technology, people could only be captivated by what nature could offer. For instance, the fractal-like visual forms in nature have a level of complexity that is moderately interesting without being attentionally excessive (Spehar & Taylor, 2013). However, computers and smartphones provide far more stimulation than nature, which can make people prone to boredom unless they have something to watch on a screen device (Hand, 2016). Pornography is another example because avid consumers can become addicted and prefer porn to real-life sexual interactions (Wilson, 2014). Such technological hyperstimulation may have far-reaching consequences if we consider the emergence of teledildonics (e.g., virtual reality sex, sex robots), which can be customized to one's ideal preferences and are themselves somewhat a solution to the modern problem of romantic loneliness, as alternatives to natural sources of intimacy (Brooks, 2021).

So while a technology may be originally invented to fulfill an immediate need, such as the production of food to satisfy hunger or the invention of mobile devices to facilitate information exchange while on the move, many of such technologies are further developed to be more palatable, attention grabbing, or usable in order to encourage their consumption alongside people's preferences for more stimulation and features (Bloch, 1995). This can make people opt for artificially enhanced stimulation over what is normal or natural. Some of this hyperstimulation is detrimental because our evolved adaptations are excessively triggered and we may not be able to cope with such high levels of stimulation (e.g., addiction to synthetic drugs), or that the stimulation leads us away from behaviors that are necessary for adaptive functioning (e.g., preferring virtual worlds over real worlds).

Hypostimulation

On the other hand, the easy availability of technological or cultural solutions can lead to a weakening of evolved adaptations and their functioning. For instance, processed food—a cultural invention to help humans digest the food—leads humans to not expend their own calories to process the food, which then contributes to obesity (Wrangham, 2009). Similarly, research has shown that at least one contributing factor to the current obesity epidemic is the widespread availability and use of microwave ovens (Kanazawa & von Buttlar, 2019). When humans consume cold food, they have to expend their own calories to increase its temperature to the body temperature before digesting it. When microwaves are used to elevate food temperature, people no longer use their innate ability to increase the food temperature before digestion and use fewer calories to digest their food. As a result, individuals who use microwave ovens are more likely to become heavier and obese.

This is true of other human physiological adaptations for thermal regulation. When humans inhale cold air, they expend their own calories to increase the temperature of the cold air in their lungs to the body temperature (van Ooijen et al., 2004). As a result, individuals living in colder climates expend more calories with each breath than those living in warmer climates (Kanazawa, 2020). While the outside temperature is not a human technological invention, warm houses that humans have designed and built to keep themselves warm in cold climates are. Humans living in

such warm houses in cold climates, with efficient central heating and insulated walls, no longer use their own physiological mechanisms to warm the air in their lungs and are consequently expected to be more overweight and physically unfit.[1] Much of the modern environment has also been designed to reduce the need for physical effort or outdoor movement, creating problems associated with sitting down for long periods, lack of physical activity or sunlight, and sedentary lifestyles (O'Keefe et al., 2011). The recent transition to work-from-home arrangements accelerated by Covid-19 also undermines our adaptive needs for in-person, face-to-face interactions, which may lead to superficial relationships and poorer organizational identification (van Vugt et al., 2024).

Attention disorders may also be due to our need for stimulation being mismatched to understimulating aspects of modern settings produced by cultural inventions (Swanepoel et al., 2022). Children are typically motivated to carry out "biologically primary" activities like social cognition, cooperation, and tool use (Geary, 2007), but schools in modern settings tend to get students to do tasks never encountered by our ancestors, such as abstract mathematics or reading where "tedious repetition and external motivation are necessary for their mastery" (Bjorklund & Pellegrini, 2000, p. 1702). Children who cannot focus are diagnosed as having attention-deficit/hyperactivity disorder (ADHD), which is often viewed as a mental problem when the problem might instead be school activities being unnatural. Conversely, ADHD traits might have been adaptive in ancestral conditions where the high levels of flexibility and reactivity associated with a hunting, foraging, and nomadic lifestyle (rather than a sedentary one) would make sensation-seeking, impulsive, and exploratory tendencies advantageous (Swanepoel et al., 2022). Taken together, technological and cultural inventions may understimulate adaptations that are necessary for optimal functioning, leading to the need for novel compensatory solutions like gyms, standing desks, socially enriched digital collaboration tools (e.g., videoconferencing), and ADHD treatments to address these emerging problems.

Modern Transportation as a Summary Example

Transportation technology is a useful example to illustrate how the three evolutionary mismatch mechanisms we proposed can be simultaneously observed. Transportation technologies such as bicycles, motor vehicles, trains, and aeroplanes allow modern humans to travel much further distances than our ancestors could. The problem of oversupply arises because we have now designed environmental infrastructures and entire lives (e.g., living far away from close kin, traveling to work) around the use of man-made vehicles such that it would be impossible for society to function without them. New problems will come if the transportation system breaks down, such as when trains malfunction during peak commute hours, bus operators go on strike, or a highway collapses. At the same time, while transportation technologies like cars address immediate problems such as food procurement (e.g., traveling to the grocer or to work in order to acquire money needed to exchange for food), they bring along stimulatory problems. The oversupply of cars allows people to avoid walking even to nearby locations, which is understimulating and responsible for poorer physical fitness. The higher speed at which people can travel using bicycles or cars can also be hyperstimulatory and render walking too slow or boring and cause modern humans to be more impatient. Road rage can be seen as an interesting manifestation of these various over- and understimulating effects, when car drivers who expect to go fast in their cars (hyperstimulated) lose it when stuck in traffic (hypostimulated)—a consequence of vehicular oversupply—and think that everyone else is a bad driver.

Potential Solutions

If we are right that evolutionary matches are unlikely whereas mismatches are abundant, ubiquitous, and inevitable as human lives get entwined with technology, what could some solutions be as we contemplate the future? The first possibility is that there are no solutions, because an effective solution would necessitate a willingness to let the most vulnerable or least capable

[1] While humans originally evolved in Africa and are thus evolutionarily designed to live in warmer climates, temperature at most times in Africa (especially at night) is below the body temperature. Therefore, humans always had to expend calories to warm the air in their lungs, just not as much as people now have to do in more extreme locations such as Siberia.

members of the group die as per natural selection processes. While this solution is technically feasible, it is not morally and ethically. From this perspective, evolutionary mismatch is a built-in design feature of any significant cultural or technological influence, given our desire to use our resources and know-how to defy nature and preserve human life and well-being as a primary adaptive strategy.

The second possibility is that we might be able to mitigate the absence of evolutionary matches by letting only the most vulnerable and the least capable members of the group consume the cultural solutions, while the majority of the group lives without them. In some sense, this is what happens in the welfare state. Division of labor and the capitalist economy based upon it are examples of human cultural technology that have allowed us to purchase most of our necessities in the open market (Smith, 1776/1982). But while most of us are able to meet all of our needs by purchasing goods and services with the money we earn from our own labor, a few vulnerable members of society are not able to do so. As a result, governments across capitalist economies create some form of welfare state—another cultural invention, and some more generous than others—so that the least capable and most vulnerable members can meet their needs in the form of welfare payments and benefits (Plattner, 1979). Its parallel in the food procurement examples used above would be a system where capable hunters and farmers procure their own food while those who are not able to do so buy their food from supermarkets.

The third possibility is to minimize technological usage while incorporating more elements of nature and other ancestral features in our lives. Because technology inevitably produces mismatch, some have called for a full return to nature and complete abandonment of technology (Kaczynski, 2016), but this is unlikely to be feasible. For instance, our bodies cannot cope without modern hygiene practices and many of us are incapable of producing our own food, nor is it practical to sacrifice time and effort to figure out how to produce food when it is readily available in supermarkets. A less extreme version of this strategy is moderate reduction of technological consumption whenever possible. While this is the easier-to-swallow remedy, the difficulty lies in determining how much self-constraint or reduction is needed, as well as which technologies are most harmful and should be reduced. Hopefully, the current article—together with an emerging line of work detailing the basis and outcomes of evolutionary mismatch (e.g., Giphart & van Vugt, 2018; Hoogland & Ploeger, 2022; N. P. Li et al., 2018, 2020; O'Keefe et al., 2011; Pani, 2000; van Vugt et al., 2024; Yong et al., 2024)—affords some insight into what is evolutionarily important and, hence, which technologies are more useful versus problematic.

For instance, life-preserving technologies like medicines and supermarket foods are useful and necessary, whereas some hyperstimulating technologies can be eliminated without significant consequence apart from short-term withdrawal symptoms (e.g., the urge to kill boredom by scrolling through social media). The evolutionary mismatch perspective is instructive on how to decide which hyperstimulating activities are more detrimental and worth reducing. For example, both video gaming and "spin" classes (stationary cycling exercise sessions led by energetic instructors using exciting music and lights) are hyperstimulating, but the former can lead to an unhealthy sedentary lifestyle whereas the latter promotes physical activity and better health. If, however, regulated video gaming helps with destressing so that one is refreshed and more productive at a later time, moderate use can still be beneficial (Hartanto et al., 2021). On the flip side, people can get addicted to spin classes, overexert themselves, and experience rhabdomyolysis, whereby muscles are so overworked that their fibers die and byproduct cells get released into the bloodstream (Brogan et al., 2017). Extreme cases of rhabdomyolysis can lead to kidney failure and even death (Sauret et al., 2002). This line of reasoning highlights the importance of taking our evolved nature into account while having an honest understanding of one's specific adaptive needs based on individual differences, thus allowing us to accept that there will be some degree of mismatch as part of the human condition and yet not let it get too much in the way of our well-being.

Another obstacle is that because technologies are culturally embedded, it is hard to stop using a technology when everyone else is still using it. A person can determine that social media platforms like Instagram or TikTok drive unhealthy social comparisons (Pinker, 2015) and conclude that it is ideal to stop using them, but if their

friends do not interact outside of these apps, the decision to stop usage can be difficult. There is a game-theoretic element to this problem because a critical mass must be on board with limiting usage before it is no longer costly for individuals to choose to do so (He et al., 2024; Mackie, 1996). Nevertheless, the growing popularity of social movements like minimalism, off-the-grid living, and "disconnect to connect" philosophies indicates collective awareness of the value of a less technologically infused lifestyle (Collins, 2018; Conroy, 2020) and may pave the way for people to regulate technological consumption more effectively. Importantly, evolutionary mismatch provides a basis for why movements that urge caution with the adoption of new technologies and emphasize the importance of aligning with a more natural or ancestral way of life are not just trendy, hippie talk.

Further Considerations

What Counts as Match or Mismatch?

A criticism of evolutionary mismatch theory is that because what counts as adaptive or maladaptive is not always clearly established, any bad or undesirable psychobehavioral outcome can be explained as mismatch (e.g., Gerstle, 2018). In response, a substantial amount of work has gone into defining evolutionary mismatch in more precise ways, such as by distinguishing between different types of mismatch, identifying their sources or how they arise, and determining whether an outcome is adaptive or not (e.g., N. P. Li et al., 2018). The current article stresses that the undesirable outcome must be a consequence of something novel due to the environmental change for it to be considered an evolutionary mismatch. By specifying a fundamental condition that cuts across the various identified criteria, we provide a crucial boundary that prevents everything "bad" from being regarded as mismatch.

One could ask: if living in a house improves the chances to survive compared to not living in a house, wouldn't couch potatoes have higher fitness than homeless people, which calls into question whether being a couch potato is really a mismatch? Importantly, the extent of interference with fitness cannot be used to gauge whether a situation is a mismatch or not. Both the couch potato and the homeless have their fitness interfered with by either having a house or not, but the couch potato's situation is a mismatch because although there is an initial improvement in fitness since survival is enhanced by having shelter, fitness decrements later emerge from being too sheltered or sedentary. Insofar as the couch potato is facing new problems that have an impact on fitness from the use of technology (i.e., their overly comfortable modern home), mismatch is present; our argument does not hinge on the severity of fitness interference. The problem of oversupply then further contributes to mismatch because once humans learn about the benefits of living in homes, it becomes available to as many as possible such that now we are typically worse off without the assumed basic right of modern housing.

Or consider the argument that because more people would die if they were unable to call an ambulance or have lower reproductive success if in vitro fertilization (IVF) did not exist, not having these technologies is less adaptive and thus a mismatch. Such arguments are expressed as: if we do not have technology such as advanced medicine now, which stipulates a counterfactual because we do not in fact live in a society without advanced medicine, more people would suffer and die, so technology is a match, not a mismatch. This compares a counterfactual present (where we do not have medicine) with an actual present (where we do have medicine), whereas our argument compares an actual past (when we did not have medicine) with an actual present (when we do have medicine). More people died in the past than they do now, so the extent of people dying is not a good benchmark for mismatch. Instead, medicine (that actually exists) is a mismatch because it allows some people who "should have" died to live. Furthermore, although technologies like medicines and IVF can help some individuals beat the odds in survival or reproduction, they still come with new problems associated with trying to defy the limits of age (e.g., aging, loneliness, cancer) or reproduction (e.g., higher risks of miscarriage or Down syndrome). And once more, through the oversupply mechanism, such technologies will likely end up becoming commonplace and drive people's reliance on them, such as when couples increasingly prioritize careers over reproduction and hope that IVF (which isn't perfect) can bring them over the line when they finally decide to have children. In other words, in certain evolutionary conditions, people are by adaptive

design meant to die, not have children, or suffer, so any cultural or technological intervention that interferes with this natural occurrence, while potentially being a match at first, typically descends into mismatch.

Another consideration is whether evolutionary mismatch should reach beyond the individual to include impacts on the environment. Recent discussions on the closely related view of evolutionary "traps," whereby industrialization and other modernizing factors create preferences for unsustainable behaviors that are difficult to stop (Søgaard Jørgensen et al., 2024), highlight harms to natural ecosystems such as the pursuit of production and profits at the expense of finite resources (e.g., depletion of fossil fuels, overfishing) and the environment (e.g., pollution, climate change), production of complex or persistent compounds that are hard to degrade, and security arms-races driving the creation of weapons of mass destruction. From our perspective, however, only inclusive fitness—the ability to transmit genes to subsequent generations, including genes shared with relatives (Hamilton, 1964)—should matter when thinking about what counts as problems that arise from mismatch due to technological use and cultural arrangements. Returning to our earlier example of modern transportation, we suggest that mismatch comes to the fore only when the impact of vehicle use on the environment affects humans (e.g., poorer quality air from exhaust fumes). These distinct effects on the environment versus the individual are underscored by how the use of environmentally friendly vehicles can prevent damage to the environment but still contribute to the problem of oversupply and, thus, mismatch for humans.

Likewise, another commonly raised consequence of evolutionary mismatch is mental health problems (Nesse, 2015), but this should matter for our mismatch perspective only to the extent that they arise from technological or cultural adoptions. Moderate levels of undesirable mental states have likely always been part of our evolved psychology (see Swanepoel et al., 2022), such as when negative mood signals being in an undesirable situation or when depressive symptoms motivate disengagement when one's prospects feel hopeless (Sloman et al., 1994), so suffering from poor mental health per se does not necessarily indicate the workings of evolutionary mismatch and would in fact be adaptive if it drives the individual to fix their problematic circumstances. Once again, our logic emphasizes that the focus should be less on whether mental health conditions are worsening and more on whether the worsening is due to technology and culture.

Are Evolutionarily Matched Starting Points Becoming Harder to Achieve?

So far, we have argued that mismatches are inevitable from prolonged cultural and technological adoption. An assumption here is that technologies would at least start out as evolutionary matches, otherwise there would be no reason to create or adopt them. Yet, given the current advanced state of technology, it is pertinent to question whether today's new, futuristic introductions are diminishing in their ability to provide significant evolutionary matches. More specifically, as technologies are increasingly introduced to deal with mismatches caused by earlier technologies, many of these new technologies might address only superficial needs while already being deep in mismatch at the outset. An example might be the modern demand for "smart" homes, or residences that use internet-connected devices to enable the remote monitoring and management of appliances and systems. On the one hand, modern homes are increasingly inundated with functions that initially came about to address specific issues, such as lighting, air conditioning, and security. The need then arose to be able to manage all of these functions in a more organized and integrated manner. Although smart homes seem to help immediately with the problem of organizing functions, they do not solve the problem of modern homes often having more functions than we truly require, which is why managing these various functions is increasingly difficult to begin with. If anything, smart home systems exacerbate this problem by coming in a commercial package where many potentially unnecessary functions are now included by default. Perhaps worse, because smart home systems rely on internet connectivity and are not always well secured, hackers can gain unauthorized access to devices, expose personal information, or even control those home systems (Kaplan, 2023). One can also think of technologies that promise greater levels of entertainment—from fancy new-age malls to immersive virtual reality gaming—that may address people's immediate needs for stimulation

but worsen the original mismatches that led to the heightened need for stimulation in the first place.

Moreover, some modern cultural and technological inventions may give people the illusion of increasing their survivability or reproductive fitness without actually doing so. For instance, teledildonics can satisfy our sexual needs without increasing reproductive success and, in some cases, even undermine it if people end up spending more time having sex with robots and other artificial entities than with real persons. People have been documented to form parasocial relationships with celebrities and media characters since the advent of television and movies (Horton & Wohl, 1956), but such relationships have now extended to YouTube live streamers and other online personalities as media technologies advance. Some of these personalities include cartoon characters such as Gawr Gura, a "VTuber," who takes on the likeness of a girl dressed in a shark costume and presently has more than 4.5 million subscribers (Y. Li, 2023; Tan & Greene, 2025). An even more extreme form of parasocial relationship is reflected in people who interact with and feel emotionally connected to Neuro-Sama, an entity that is entirely driven by artificial intelligence. Although such parasocial relationships may allow consumers to feel less lonely during engagement, they do not address the deeper personality or lifestyle problems that gave rise to the loneliness in the first instance. These various examples suggest that the initial evolutionary match offered by new cultural and technological introductions may sometimes be hard to determine given the complexity of human needs associated with living in modern and increasingly artificial environments (Table 2). Further research is warranted to

Table 2
Technologies and Their Initial Evolutionary Match and Subsequent Evolutionary Mismatch

Technology	Initial match	Subsequent mismatch
Mass-produced sweet and fatty foods	Calories, energy, prevention of hunger	Overeating, obesity, diabetes, finding natural foods unpalatable
Human-made shelters, houses	Safety from predators, enemies, and harsh weather	Sedentary living, insufficient physical and outdoor activity, obesity
Modern medicine	Prevention of illness, well-being	Eradication of good bacteria, weaker immune systems, reliance on medicinal supplements, side effects such as irritable bowel syndrome, multiple sclerosis
In vitro fertilization	Increased chance of reproduction at a less fertile life stage	Higher risk of miscarriage and Down syndrome
Microwave ovens	Ease of digestion, killing pathogens	Less calories expended digesting food, obesity, less developed gut bacteria, poorer gut health
School classroom environment	Transmission of knowledge, learning	Inability to focus, ADHD
Computers and digital technology	Productivity, efficiency, improved communications, enhanced processing, and memory storage, information source, entertainment	Sedentary living, remote working, lack of social interaction, addiction to screen devices, finding nature boring
Internet as a voice platform	Communication, social interaction	Information provided by nonexperts, difficulty discerning the quality of information misinformation
Social media	Communication, social interaction	Unhealthy social comparisons, social status anxiety, social status inflation, difficulty discerning status
Media technologies	Information source, entertainment	Feeling bored unless watching something, parasocial relationships, sedentary living, insufficient physical and outdoor activity
Pornography, teledildonics	Satisfaction of sexual desire, opportunities for practice before actual encounter	Addiction to porn/teledildonics, preference for artificial/virtual sex over real sex
Smart homes	Organization of enhanced home functions	Sedentary living, insufficient physical and outdoor activity, obesity, vulnerability to hacking

Note. ADHD = attention-deficit/hyperactivity disorder.

understand the adaptive utility of technology as we progress into the future.

Concluding Remarks

Theodore John Kaczynski (aka "The Unabomber") was perhaps one of the best known critics of modern technology, what in previous centuries was called a Luddite. Apart from being a mathematical genius, Kaczynski (1995) was also well aware that "the social and psychological problems of modern society" are attributable "to the fact that society requires people to live under conditions radically different from those under which the human race evolved and to behave in ways that conflict with the patterns of behavior that the human race developed while living under the earlier conditions" (see Point 46). Ultimately, his concerns about how industrialization and capitalism are untenable in the long run drove him to carry out mail bombings aimed at individuals poised to make crucial technological advancements, which led to several fatalities and injuries and his subsequent arrest and lifetime incarceration. In a sense, Kaczynski was not only a pioneer theorist of evolutionary mismatch but also a proponent and practitioner of mismatch elimination, albeit using extreme means. While we concur with his observation that technology necessarily and inevitably leads to problems for humans, we believe that the complete abandonment of modern technology and return to primitive life is neither prudent nor necessary, let alone his use of violence and terror to achieve such goals. The development of viable interventions will likely involve a more moderate approach to understanding how modern technology leads to problems for humans in light of our evolutionary design and striking an enlightened balance between technological use and needs satisfaction.

It is important to note that while we tried to present what we believe are the most illustrative cases of our ideas, they are likely inexhaustive given the huge range of technologies in the world today. Our aim was to be as broadly encompassing as possible, which may compromise on the specificity of our examples and leave us vulnerable to unforeseen exceptions, but we gladly invite others to challenge or build on them. What we consider to be more important is to encourage deeper thinking into the consequences of our cultural and technological modes of life, in particular why they tend to lead to mismatches rather than matches, and draw attention to the value of evolutionary approaches in guiding such analyses.

On a final note, perhaps what makes the evolutionary mismatch hypothesis particularly intriguing is its challenge to the view of humans as supposedly rational beings (see Yong et al., 2021)—that logically, being in a "better" (e.g., cleaner, more efficient, safer, more abundant) state made possible by technology should make us feel and live better, but that does not necessarily happen. Despite (or because of) our modern comforts and affordances, we have a tendency to overeat, be lazy when it comes to physical activity, and easily get addicted to all kinds of stimulation. This attests to the indispensability of an evolutionary perspective which emphasizes how humans evolved to do certain things given certain environmental inputs. In a mismatched world, a handful of us cannot help but act in ways that appear "irrational" or maladaptive, because that is how we evolved to be.

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