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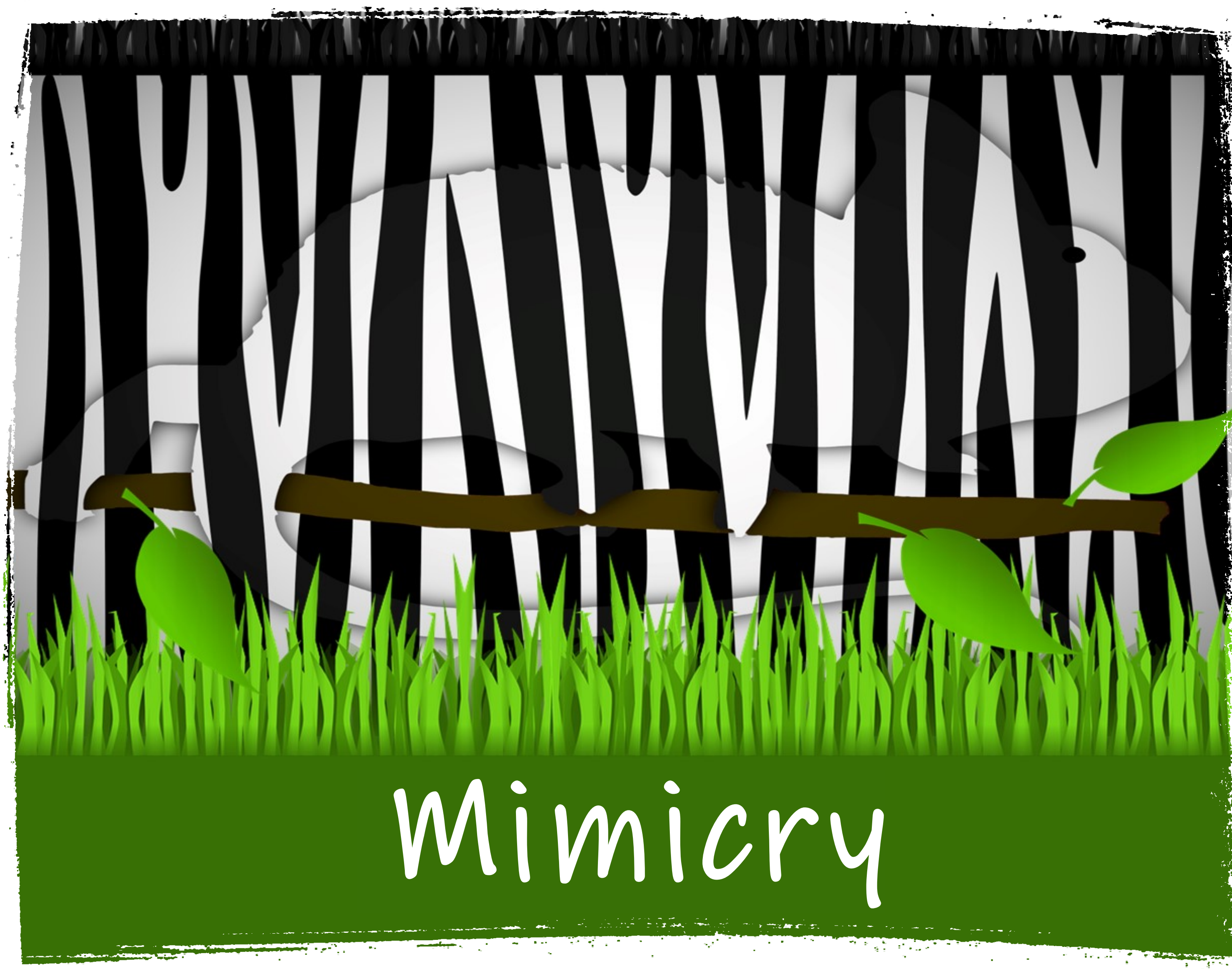

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Preface

"The most dangerous physicians are those who can act in perfect mimicry of the born physician."

Friedrich Nietzsche

Dear Reader,

We are closing in on the second year of a worldwide pandemic and I still very much hope that all of you are sound and safe. This year we were struggling as well with a lot of service issues, but with the aid of good friends, we are back on track, albeit with some delay again. I'm personally sorry, but I am looking ahead into a new year with new projects in progress that will help us take JUnQ to a new level. This is about time since, with this issue, we have finished up our first decade of JUnQ! Very much has happened since then and we will feature some voices of the past and more in our first issue in 2022. One new thing that will be already featured in this issue is the "What The Fact!?" section. The Questions of the Month QotM are no more. Instead, we will feature similar articles under the name of "What The Fact!?". We will put more effort into creating a steady flow of entertaining but informative short articles about interesting topics that will be featured online first. A selection of the topics will then be featured in our next issue.

But before we are too concerned with the past or the bright future ahead of us, let's focus on the current issue and its topic. This time we will dive deep into the subject of mimicry. The first things that might jump into your mind are chameleons (of course, it's also on the cover) and other animals which are using colours to deceive enemies or prey alike by mimicking their surroundings. But mimicry is so much more: what if I tell you that you have done a good bunch of mimicking since you got up today by the time you are reading this issue? Even if we look much closer at the building blocks of ourselves we will find that mimicry is also very much present in the world of cells and molecules!

— Kevin Machel

Opinions

Smile and the Whole World Smiles With You

Mimicry and the impact it has on our social lives

Ina Hönemann

Imagine you are sitting at a table during lunch and your friend or colleague smiles at you. What do you do? You reflexively return a smile. You do not think about it. Indeed, you are also returning a smile if your mind is otherwise occupied. When someone smiles at us, we (usually) return a smile. This happens automatically, around 300 ms after the original smile. It enhances our mood and eases the start of a potential conversation. The underlying phenomenon of the reflexively returned smile is mimicry, i.e. the automatic imitation of a just observed behaviour. Thereby, we must distinguish mimicry from intentional imitation. If we deliberately decide to return a smile to be polite, we intentionally imitate. If we unintentionally and even unconsciously raise the corners of our mouths, we mimic. Solely the observation of a smile suffices as trigger. Accordingly, mimicry can be defined as “a phenomenon where merely observing another’s behaviour elicits a corresponding action in the observer”.[1] Thereby, the returned smile, i.e. the corresponding action in the observer, must not completely match the original behaviour. Mimicry can be subtle. Barely raising the corners of the mouth already counts.[1,2]

Figure 1: People mimic facial expressions[3] and posture.[4,5]

Mimicry is not restricted to smiling, even though smiling has a special role as an affiliative signal (as we shall see later). It may be surprising as it happens without conscious awareness, but mimicry takes place in almost every social interaction. Have you ever wondered why you have to yawn as soon as someone else yawns? The answer is mimicry! Unlike most mimicry reactions, yawning is too obvious to be missed. People mimic facial expressions, verbal characteristics, emotional responses, motor movements such as yawning and even health-related behaviors like smoking. Hence, mimicry can be divided into four subsections:[6-8]

1. Behavioural mimicry: The mimicry of mannerisms, posture, gestures and motor movements, e.g. face touching, foot shaking and handshake angle & speed. Here, the behaviour is repeated in up to 3-5 seconds.

2. Verbal mimicry: The mimicry of speech characteristics and patterns, such as speech rate, utterance duration, latency to speak or accent. Already newborn babies verbally mimic by crying after hearing another baby cry.

3. Facial mimicry: The mimicry of emotional as well as neutral facial expressions. Mimicking a facial expression can help to understand the underlying emotions as the muscle movements result in facial feedback, which enables emotion recognition. Accordingly, facial mimicry can lead to emotional mimicry.

4. Emotional mimicry: The mimicry of emotional expressions. Contrary to the mimicry of most gestures emotional mimicry is intrinsically meaningful because emotional expressions signal socially relevant information and behavioural intentions.[2]

Why do we mimic such a huge variety of gestures and expressions? When we return a smile, we send a social signal. We want to get along or even affiliate with our opposite. We know from experience that smiling enhances our mood and the mood of our opposite and makes us feel closer to each other. The research not only confirmed the affiliative consequences of mimicking a smile but of mimicry in general. In 1999, the chameleon was chosen as a metaphor for unconscious mimicry:[9] Just as chameleons change their color to blend in with their environment, humans alter their behaviour to blend in with their social environment.

The so-called "chameleon effect" was described as a social glue that helps to bind interaction partners together. Mimicry facilitates liking, affiliation, empathy and feelings of closeness and can help to understand emotions. It promotes important aspects and needs of social life. Therefore, it is not surprising that mimicry is the default in most social interactions. As mentioned in the beginning, being occupied otherwise does not restrain us from mimicking a smile of a friend. Indeed, a study[10] from 2016 revealed that participants under cognitive load mimic the smiles of positively described persons automatically. Additionally, behavioural mimicry even increases under cognitive load. The default character of mimicry is supported by the fact that neither the mimicker nor the mimicked person notice anything.

Does this imply that we always mimic our surroundings? No! Even though we can not consciously control the mimicry reactions, our underlying intentions shape the amount of mimicry we display. We do not want to affiliate with everybody and always. Some situations and constellations will lead to less mimicry. For example, negatively described persons are not mimicked. That fits our experience. Imagine someone you do not like smiles at you. Imagine you are in a bad mood and do not want to engage in social interactions. In both cases, you will not return a smile.
Individual differences play a role, too. Extroverts and adults with secure attachment styles mimic more than introverts and adults with insecure attachment styles, respectively.

The different factors, which increase or decrease the amount of mimicry in social interactions, are called "moderators" (see Figure 2).[6,7] These moderators include our inner motivations and attitude as well as external circumstances that shape mimicry. We already met the most important moderators: the goal to affiliate and pre-existing rapport, you rather mimic a friend as opposed to someone you do not like. We also mentioned mood and emotion: if you are in a bad mood, you will not return a smile.

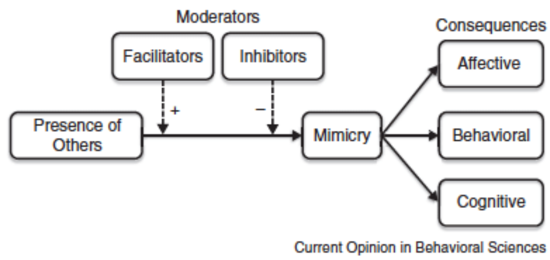

Figure 2: Mimicry occurs in the presence of others and is moderated by facilitating or inhibiting factors.[7]

The goal to affiliate manifests in different ways, for example, through the need to belong. Experiments from 2008[11] investigated if and how exclusion by strangers leads to an increase of mimicry. Participants who were excluded during an on-line cyberball game mimicked a subsequent partner more. They used mimicry to bond with someone new and, thereby, to recover from exclusion. To test the selectivity of mimicry with regard to the need to belong a second experiment was set up. Female participants got to know the gender of the other players and, thereby, if they belonged to the in-group (just female teammates) or to the out-group (just male teammates). After being excluded, they interacted with a female (in-group confederate) or a male (out-group confederate). In the no-exclusion control condition, participants did not play at all. Females that were excluded by females and afterwards had the chance to restore their status inside the group, due to interaction with another female, mimicked the most (see Figure 3). They used mimicry as a way of saying: "I am too just like you". Hence, mimicry is used selectively, flexibly and strategically. It occurs more often if it holds promise.

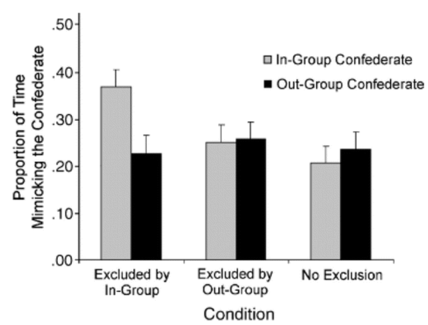

Figure 3: Covariate-adjusted mean proportion of behavioural mimicry.[11]

In general, we mimic persons of our group, i.e. in-group members, to a greater extend compared to persons that do not belong. (Not surprising considering that we mimic those we like more!) The group can be fixed, as in the case of gender, or arbitrary. Letting 4-6-year-olds choose a group by choosing a color, increased their mimicry of adults belonging to the same color. Those adults wore shirts in the corresponding color and the belonging was pointed out. It follows that already children act like little chameleons to blend in with their social environment.[12]

It is a small step from group membership to similarity. For example, sharing the same name or agreeing on various viewpoints promotes mimicry, too. In addition, people mimic attractive persons to a greater extend. (I do not know about you, but most people rather bond with the handsome.) However, being closely committed to someone else lowers this effect. Mimicry can communicate romantic interest and the lack thereof can shield a relationship. We can thus recognize the goal to disaffiliate as an inhibitor.[6]

Another inhibitor is the lack of morality. Recent studies[13] investigated the effect of morality compared to sociability or competence-related information. The authors argue that morality has a primacy on decisions about whom to trust. Being trustworthy is the key information we look for before engaging in interaction and, therefore, it affects affiliation goals. Consequently, the authors tested if morality has a leading role in influencing mimicry. Before meeting a confederate, participants read letters describing a situation in which the confederate acted morally/immorally (returning/keeping a found wallet) as opposed to friendly/unfriendly or competent/incompetent. The confederates, in turn, were instructed to perform three specific movements (rubbing the arm, touching the face, moving the head) during the subsequent, recorded conversation. Independent judges rated the extend to which mimicry occurred. Only the description as immoral lead to a decrease. The unfriendly or incompetent described confederates were not mimicked less. This result confirms the power of morality in affecting mimicry.

Now, we acquired a well-rounded overview of the inner factors that shape mimicry: the goal to affiliate, pre-existing rapport and liking, similarity and morality. Against this background, it is not surprising that mimicry itself creates affiliation, feelings of closeness, liking and trust between the involved individuals. This is a strong statement. It implies, that mimicry shapes our social lives or rather our relationsships and their origins. (No relationship without liking.) Since mimicry is a central part of interactions, we developed expectations on its right amount. Imagine someone meticulously mimics your behaviour. Accurately moving the arm like you, touching the face on the exact same spot you touched yours. Will you feel closer to this person or will you feel shivers running down your spine?

We see, there are exceptional cases in which mimicry does not increase liking. For example, mimicking unfriendly behaviours casts a poor light on the mimicker. Other examples are mimicking out-group members or disliked persons. On the other hand, mimicking an out-group member decreases prejudice on the side of the mimicker. That could lead to a win-win situation or at least a trade-off, because mimicked individuals become more prosocial. Here, we see one of the behavioural consequences indicated in Figure 2: mimicked people often act more helpful towards the mimicker as well as towards others. In the eyes of the mimicked individual, the mimicker appears to be more persuasive. Consequently, mimicry can alter our behaviour as consumer, too. Salespersons that mimic costumers achieve greater success.

Cognitive consequences can be convergent thinking (being mimicked) or divergent thinking (not being mimicked). Mimicked persons are better at recalling positions of objects and (maybe) they conform more likely to stereotypical expectations. Mimicry fosters learning. Learning to appropriately behave in your social environment goes hand in hand with preferentially mimicking in-group members. You better act like an in-group member to catch the bodily and emotional reactions selected by your group. In that sense, mimicking someone signals: "I value you as a good source of information about suitable behaviours." Mimicry may also help to understand the emotions of our opposite, but to explore that, we must further investigate emotional mimicry first.[6,7,14]

Figure 4: Avatar expressing anger and happiness.[2]

As facial emotional mimicry is subtle (see Figure 4) it is difficult to spot. Furthermore, it is fast, it occurs within 300-500 ms.[2] To cope with that, it is measured via facial electromyography (fEMG). When muscles are contracted, they elicit electrical impulses, which are detected by the electrodes of the fEMG. FEMG even reveals expressions below the visible threshold. However, faces are not infinitely large and, thus, the number of electrodes that can be applied is restricted. On the other hand, emotional expressions can involve several muscles. That is one reason why research often focuses on the expressions of anger and joy. Frowns and smiles are usually determined through the activity of the corrugator supercilii ("frowning muscle") and the zygomaticus major ("smiling muscle"). Another reason is the importance of these emotions. Smiling is a representative of affiliative expressions (e.g. happiness and sadness) and frowning is one of antagonistic expressions (e.g. anger and disgust). In order to signal our affiliative intentions, i.e. to say: "I like you", we should particularly mimic affiliative expressions and refrain from mimicking antagonistic expressions. Mimicry of smiles is often present even with a lack of affiliative intentions. Smiling as strong affiliative signal may suffice to motivate affiliation and thus mimicry. Seeing only the eye region of a smiling face did not prevent participants from a mimicry response. Furthermore, priming neutral expressions with emotions leads to mimicry of the alleged happy and sad faces. It follows that we do not simply mimic muscle movements but rather the meaning behind them.[2]

That mimicry reflects meaning is supported by an experiment from 2018.[1] Participants played games with an android (the robot not the operating system) either as their teammate or as their opponent. The outcome of the game was communicated through the expressions of the android ("smiling" = android won, "frowning" = android lost). Participants being teammates of the android reacted with spontaneous mimicry as expected. Participants being opponents reacted incongruent to the android's expression reflecting their own emotional reaction to the outcome. Interestingly, the timing of the facial responses as well as their magnitude were equal. The teammates being opponents reacted as fast as the others. They displayed "counter-mimicry" and, thereby, mimicked the meaning the observed expression had for them. Additionally, we see how strategic context reshapes spontaneous mimicry. The same applies for social context. A study from 2014[1] highlights the flexibility of mimicry in the context of power. The mimicry reactions of participants depended on their status. Everyone mimicked a frown of a high-status person in under 1 s. Participants with low status displayed a smile just after the frown (2-4s) generating a pattern of mimicry followed by counter-mimicry. Participants with high status mimicked the smiles of inferiors, but not of coequal participants. They only responded with a smile among themselves as they counter-mimicked angry expressions. In summary, context affects the meaning of expressions and impacts mimicry.

Can we understand the emotions of our interaction partner by mimicking his or her expressions? Theories supporting this hypothesis are called "embodiment theories" and claim that higher-level processing is grounded in the sensory and motor experiences of the individual. While observing (or thinking about) a behaviour one can reenact or mimic that behaviour in order to promote conceptual processing.[1]

Indeed, mimicry helps to distinguish between true and false smiles. In a study from 2014,[15] participants wore plastic mouthguards to restrain them from smiling and to block their mimicry reactions. They watched videos from persons smiling to amusing or neutral stimuli, hence, showing true or fake smiles respectively and rated the genuineness of the smiles on a scale from 1 to 5 (1=fake smile, 5=true smile). To account for the possibility that wearing a mouthguard may be distracting, the participants in the control group had to firmly hold a stress ball. Additionally, in a third group (free) participants wore a finger heart rate monitor to make them nearly as aware of their bodies as the participants wearing the mouthguard. The mean ratings of all groups are shown in the following figure.

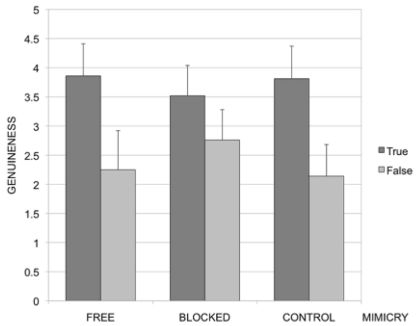

Figure 5: Genuineness ratings of true and false smiles in the free (finger cuff), blocked and muscle-control (squeeze ball) condition.[15]

We clearly see that blocking mimicry has an influence on recognizing false smiles. True smiles were rated less genuine and false smiles more genuine compared to the control groups.

So, did we figure out how people decode emotions of others? Not quite. Contrasting indications exist. People with Mobius syndrome, which causes facial paralyses, are in no way inferior when it comes to recognizing emotions. As their ability to mimic facial expressions is always blocked, they may developed alternative strategies to understand emotions. Anyways, we can not state that mimicry always leads to emotion recognition, but at least these phenomena are not detached from one another.[1]

Maybe you have already noticed that the research mainly focuses on the dyad, the mimicker and the mimicked. What about the other persons around? This issue was addressed in a study from 2020.[16] The authors argue that the mimicked person is the initiator of a movement and, therefore, gets to "lead" the mimicker. In the eyes of third party observers, the mimicker should look like a "submissive chameleon". In a series of experiments participants watched different videos of two interacting persons and rated their dominance. (The videos are accessible here.) In the same movement condition the video showed one person mimicking movements of the other, namely, touching the hair or touching the chin.

The results are displayed in Figure 6. The mimicker, i.e. the "responder", was rated as less dominant, which meets the expectations. In the absence of mimicry (no movement condition), the pattern flipped and the initiator appeared submissive. (Your movements are not followed? You are in no way in control.) A second experiment concluded: a mere action-response pattern (action followed by different movement) as well as the actual matching of the movement creates the submissive appearance of the responder.

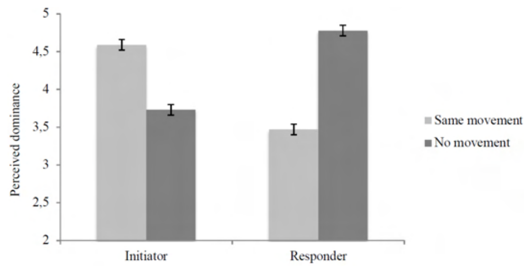

Figure 6: Perceived dominance in the case of mimicry (same movement, initiator = mimicked person, responder = mimicker) and no movement.[16]

Mimicry is automatic and it happens unconsciously. We can not switch it off if we want to be perceived as dominant. Furthermore the price would be too high, since mimicry smooths the interaction of the dyad. To be more precise the mimicry of affiliative signals serves interaction quality, whereas antagonistic mimicry does not.[1] (You are frowning at me and I am frowning at you, I am wondering why interaction quality is low.)

We interpret emotional signals and answer them by revealing our emotional intentions through mimicry. Consequently, mimicry has a huge impact on our social lives: it helps to build or maintain social bonds. Mimicry promotes relationships of all kinds and creates effective social groups. Even though the mimicker appears submissive in the eyes of a third person, the positive consequences of (affiliative) mimicry are astonishing. In other words, there are good reasons for the world to smile with you.

Read more:

[1] Andy Arnold and Piotr Winkielman, **2021**. The mimicry among us: Intra- and inter-personal mechanisms of spontaneous mimicry. *Journal of Nonverbal Behavior*, 44:195-212.

[2] Ursula Hess, **2020**. Who to whom and why: The social nature of emotional mimicry. *Psychophysiology*, 58(1):e13675

[3] Jozef Turóci, CC BY 2.0, https://www.flickr.com/photos/43412438@N07/4843352919

[4] ESA/S.Bierwald, CC BY-SA IGO 3.0, https://www.flickr.com/photos/37472264@N04/14656564138

[5] Beth Scupham, CC BY 2.0, https://www.flickr.com/photos/22519875@N08/7311993342

[6] MTanya L. Chartrand and Jessica L. Lakin, **2013**. The antecedents and consequences of human behavioral mimicry. *Annual Review of Psychology*, 64(1):285-308. PMID: 23020640.

[7] Korrina Duffy and Tanya Chartrand, **2015**. Mimicry: Causes and consequences. *Current Opinion in Behavioral Sciences*, 14.

[8] Korrina Duffy and Tanya Chartrand, **2017**. *Moral Psychology*, chapter From mimicry to morality: The role of prosociality. The MIT Press.

[9] Bargh JA Chartrand TL, **1999**. The chameleon effect: the perception-behavior link and social interaction. *J Pers Soc Psychol.*

[10] Heidi Blocker and D. McIntosh, **2016**. Automaticity of the interpersonal attitude effect on facial mimicry: It takes effort to smile at neutral others but not those we like. *Motivation and Emotion*, 40:914-922.

[11] Jessica L. Lakin, Tanya L. Chartrand, and Robert M. Arkin, **2008**. I am too just like you: Nonconscious mimicry as an automatic behavioral response to social exclusion. *Psychological Science*, 19(8):816-822. PMID: 18816290.

[12] Sabine Hunnius Johanna E. van Schaik, **2016**. Little chameleons: The development of social mimicry during early childhood. *Journal of Experimental Child Psychology*, 147:71-81.

[13] Michela Menegatti, Silvia Moscatelli, Marco Brambilla, and Simona Sacchi, **03 2020**. The honest mirror: Morality as a moderator of spontaneous behavioral mimicry. *European Journal of Social Psychology*, 50(7):1394-1405.

[14] Liam C. Kavanagh and Piotr Winkielman, **2016**. The functionality of spontaneous mimicry and its influences on affiliation: An implicit socialization account. *Frontiers in Psychology*, 7:458.

[15] Wood A Rychlowska M, Cañadas E, Krumhuber EG, Fischer A, and Niedenthal PM, **2014**. Blocking mimicry makes true and false smiles look the same. *PLoS ONE*, 9(3).

[16] Oliver Genschow and Hans Alves, **2020**. The submissive chameleon: Third-party inferences from observing mimicry. *Journal of Experimental Social Psychology*, 88:103966. Link to videos: https://osf.io/wtzrf/?view_only=7e79c6ab20874e49ad992b22a7f8ebfb

Hijacking Nature's Molecular Defence Mechanisms - RNAi bio-pesticides

Kevin Machel

Figure 1: A tractor deploying pesticides. By aqua_mech.

Figure 2: A Grapevinemoth larvae feeding on a grape vine. By Graibeard.

As a necessary evil, we have to utilize measures of pest control to protect our crops, vegetables and fruits from a variety of different organisms. Annual losses due to pests are estimated on a global scale ranging from 20% to 40% total loss.[1,2] This scale makes it evident that firm control of pests is desperately necessary to feed the current world population. On the other side, a decline of roughly 75% in biomass of flying insects during the past 30 years creates the need for more precise pest control.[3] A technology that has been investigated for some time and seems very promising regarding selectivity is RNA interference (RNAi), a potential bio-pesticide. This technology mimics molecules present in the natural defence mechanisms and thereby utilizes them against pests.

To understand this conflict of interest between pest control and ecological concerns the Grapevine Moth is a good example. The larvae of the grapevine typically feed on the leaves of vinegrapes in vineyards. At the beginning of the 20th-century, scientists in the United States were working on pesticides based on *Paris Green* to control a multitude of pests. The intensive green colour pigment is a toxic arsenoxide-copper salt with the formula $Cu(CH_3COO)_2 \cdot 3Cu(AsO_2)_2$. For the dispersion onto the fields, a formulation of one part Paris Green and two parts of mineral oil was found to be the most effective. From potato, corn and other crop fields to vineyards, the new pesticide was commonly used. Needless to say that this early method of pest control was extremely harmful to anything in the direct environment and even to the plants themselves. Still, the yield increased due to the lack of any pests bothering the plants. Hence, the negative impact of pest control was countered by the overall increase in yield.

Since then, a lot has happened and a great variety of pesticides has been invented and deployed on a megaton scale. In the latter half of the 20th-century, etymologists and beekeepers registered a general decline in the biomass of flying insects. This dawning extinction is driven by a multitude of factors but the pollution by pesticides is a major contribution.[4] As several important insect species are drawing close to extinction, the need for highly selective pesticides sparks the idea of using novel genetic methods to arm plants selectively against their pests. The method in question is called RNAi which is an abbreviation for *Ribonucleic Acid interference* and describes strands of RNA that have a sequence complementary to strands of target RNA. Specifically, RNAi strands can bind onto so-called *messenger Ribonucleinacid* (mRNA) which is used by cells to create proteins.

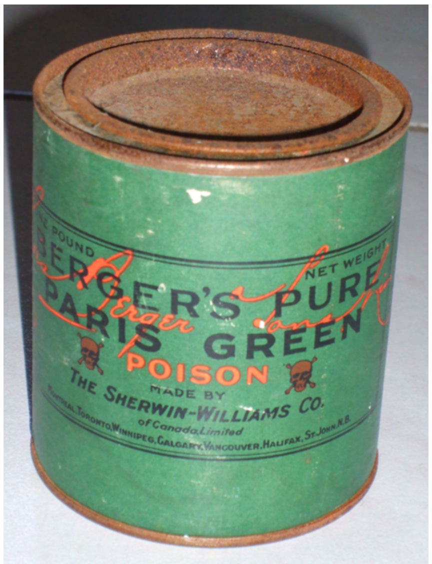

Figure 3: A bucket of Paris Green paint, by The Sherwin-Williams Co.

After entering the cell in the form of double-stranded RNA (dsRNA), the RNAi is cut into smaller pieces by *Dicer*-proteins. The resulting small interfering RNA (siRNA) then binds to *Argonaut*-proteins (Ago)which recruit other proteins for host defence. On binding onto the Ago, the siRNA can bind the target mRNA with a complementary sequence. This binding triggers the assembly of a host defence complex called *RISC* which recognizes the target mRNA as a hostile RNA (e.g. viral RNA) and degrades it accordingly.[5]

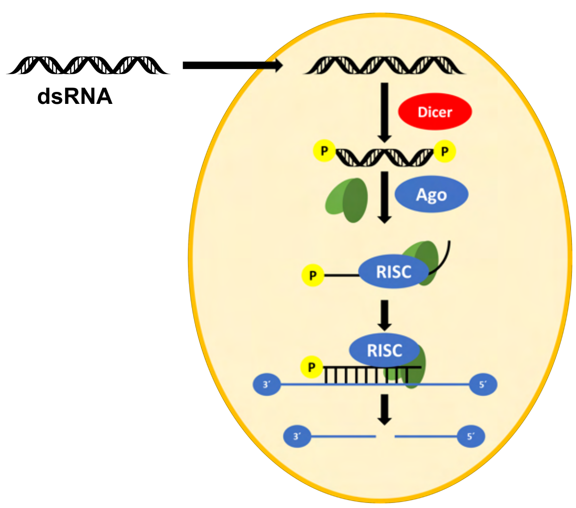

Figure 4: Mechanism of RNAi by importing dsRNA into the target cell.

In the event of an infection of the host with an RNA virus, this mechanism is triggered since the viral RNA is cut down by Dicer and the small strands bound by the Ago. The RISC complex then uses this small strand of viral RNA to detect and bind more viral RNA within the cell and degrade it. The RNAi, therefore, hijacks the host's RISC complex that is in charge of detecting hostile RNA and primes it to attack its mRNA.[6] But also viruses use these mechanisms in return to disarm the host defence.[7] One can only marvel at how immensely insidious and elegant this method is. As an effect, the translation of that specific target protein in the cell is inhibited due to a lack of mRNA. By inhibiting the translation of critical proteins, the cells can not survive any longer. Thereby the target of the RNAi will inevitably die within hours or days after uptake. The duration after which the target dies highly depends on the protein that is targeted by the RNAi. Furthermore, it is dependent on the mechanism of action. Using RNAi, there is no limitation to a certain kind of target. The approach also allows inhibiting the development of various features. Experiments using Drosophila and targeting its Hunchback Gen resulted in the incapability of the cells of the embryo to differentiate properly to form an abdomen.

Figure 5: RNAi phenotype petunia crop by A. Marjori, A. Matzke and J. M. Matzke. credit Jan Kooter for the left and middle images and Natalie Doetsch and Rich Jorgensen.

RNAi does not only affect the target specimen but also eggs within the specimen. Thereby, the next generation is targeted directly as well.[8] By selecting a target that merely inhibits the metamorphosis into the adult stage the larvae will still feed on the plants and cause harm to the crops but they will not be able to reproduce. The criteria for selecting the target besides speed and efficacy is the uniqueness of the selected mRNA sequence and resulting RNAi. Generally speaking, RNAi is slower than conventional pesticides since the translation of proteins is also rather slow compared to other neurotoxic agents like nicotinoids. But this minor disadvantage is a small trade-off for the great advantage of the method, the selectivity.

Since the genome of a species is (with minute variations) unique, the mRNA sequences for the proteins are unique as well. Thus, it is possible to select an mRNA target that is characteristic of the grapevine moth, for example. Even if a protein is selected that is very similar to a humanoid protein, it is unlikely that the RNAi would bind to the non-target mRNA as long as at least one or more positions in the sequences are different. To test this hypothesis, experiments were conducted where RNAi which targets specific or non-specific viruses was given to bumblebees without any detectable toxicological effects. Although toxicological effects were not observed the unspecific RNAi, however, did trigger antiviral responses. Since the results are quite promising, toxicity conflicts can be avoided by scanning the genome databases for complementary sequences in other species.[9] This requires that the genome of other species in question are completely sequenced and available, of course. Even with the breakthroughs in genome sequencing, this will take some time.

Figure 6: "Gene sequencing lab, Sackler Institute for Comparative Genomics" from the company GSZ.

Another advantage of the method is that RNAi is a bio-molecule itself and the principle of reulatory RNA is already present in nature. Plants have been using small regulatory RNA to defend against viruses.[10] Since RNA is a bio-molecule, it also tends to degrade very quickly without any protection from the environment. This makes the transfer of RNAi into the plants somewhat difficult. One way is to encapsulate the RNAi within liposomes and treat small clay particles with the liposomes and use them for dispersion. These so-called SIGS (Spray Induced Gene Silencing) are then used to treat crops commonly by simply spraying them over a field. Another more critically-viewed method for transportation is to genetically edit the plants to produce the RNAi themselves. Instead of an external deposition of the double-stranded RNAi, it is injected into the plants. Of course, injecting every plant or crop in a field would impractical to say the least. Therefore, the injection is already done in the seed stage and will stay in the plant during its development into the adult plant.

Whether the RNAi is deposited via an internal or external mechanism does not matter for the transportation process of RNAi. Since RNA itself is a very delicate molecule, which is easily degraded outside of a sterile laboratory, it needs to be packed very well. The current dawn of mRNA vaccines made that very clear since they have to be stored properly and are also very susceptible to several factors like temperature changes, UV-rays and many more. All these factors are easy to control in a lab or medical environment but hardly so on our fields. Aside from the challenges of deploying the RNAi onto the crops, since they are so susceptible to the environment, they need to be deposited more often than regular pesticides. On the plus side, the fast deployment of vast amounts of mRNA vaccines has proven that is possible to produce these kinds of molecules on an industrial scale and at least pack them properly into liposomes. Until recently that had been viewed as the major challenge in order for RNAi to be used on a large scale.

Besides the evaluation between effort and possible gain, another consideration is much more important concerning the acceptance of the use and deployment of genetically modified organisms (GMO). Although the first GMOs were already created and used in an agricultural sense during the 1980s, there is still a general distrust throughout the society towards GMOs. To utilize the full potential of RNAi technology to reduce the usage of regular pesticides, this distrust has to be overcome. From one scientist to another, I am rather confident to say that we might very quickly agree that the risks are lower compared to regular pesticides. But let's assume we wanted to discuss the risk-benefit evaluation with our friends that are by chance, not scientists. One very common fear of opponents of GMOs is that the consumption of GMOs in some ways changes something in our bodies. This sounds rather vague but sums up most fears about GMOs.

Figure 7: "Rally to Support GMO Food Labeling" from CT Senate Democrats.

For example, the insertion of the "anti-freeze gene" into Tomatoes incited fears of the insertion of this alien gene into our DNA by the mere ingestion of the GM-Tomatoes.[11] This common misconception can be simply dismissed by reminding ourselves that the DNA of organisms ingested by us are broken down by digestive system proteins into mere molecular pieces. However, the effect of these pieces on our microbiome has yet to be determined.[12]

There is only one exemption that can be regarded as a more or less fact-based fear. There are already GM-Plants that have pest defence mechanisms inserted into their genome. Most commonly found are BT toxins and so-called CRY Toxins which both are naturally occurring toxins.[13] The fear of eating something that naturally has toxins can understandably induce the fear that this might be unhealthy in one way or another. So arguably these first-generation GM-Plants are not ideal, especially about being not very specific in their toxicity. They are still quite capable of affecting species that feed on pests or other insects.[14] But even these not very ideal GM-Plants have been examined closely by scientists in order to determine their toxicity against humans before being allowed for consumption. Another common fear is that we are not able to control a GMO once it is outside the lab. There are fears of GMOs messing with the genome of the organisms living from it, which comes close to the first fear discussed before. But the loss of control might not be vertical up the food chain but rather within the plant itself. Let's assume we wanted to insert genes into the genome of a plant to let the plant produce RNAi by itself, for example. The insertion of genes into a genome requires the insertion of promoters to activate the genes as well. There is a chance that through the insertion of these promoters other genes might be activated or deactivated as well. This can result in an unstable genome that, if it spreads and mingles with the naturally occurring plant, could lead to its extinction or result in a decrease of usability to us. So far scientists still have not reached a conclusion about this.[15] But this definitely presents a mechanism of losing control over the GMO. The spread of GMO-Genes throughout the environment by pollination of non-GM-Plants with GM-Plant pollen is hard to completely curb. On the other side, we have already seen that this happens to a small extent with classically cross-breed plants. In rare cases, this leads to a introgression of non-GMO populations.[16]

One quite enjoyable manifestation of the evaluation of benefit and risk of genetic engineering is found in the 1993 movie Jurassic Park. There, the question arises if men should genetically re-engineer an extinct species in the form of dinosaurs. Although this is arguably not a realistic scenario so far, the criticism towards the use of gen-technology from one character is quite fitting until this day.[17] Ian Malcolm, depicted as a mathematician and expert in the field of chaos theory, claims that genetic engineering is arguably the most powerful tool ever created by humans and that once outside, there is no guarantee that one will be able to control these organisms. And although we have discussed and dismissed the common fears, he is right by saying this. We still have to do a lot of research and can never be certain that no complications from the usage of this technology will arise ever. But so far, it is already evident that the risks that can be estimated or are already known resulting from this new technology, in comparison to the methods already in use, are much smaller. Many challenges are still in the path towards a real competition of novel

RNAi technology and regular pesticides. They will never be as potent and until recently more expensive to produce. For every pest, a specific RNAi has to be designed first which then will only be useful against this one

Figure 8: Ian Malcolm in Jurassic Park - 1993 ©Universal Studios.

species. Exactly that is also a great benefit. Not having to abstain from using pesticides but instead using pesticides that will most definitely only affect the pest in question is groundbreaking. If the challenges and especially the distrust toward GMOs or gen-technology like RNAi are overcome, we might gain a powerful new tool to protect crops and crucial insects alike. If we are going to use RNAi with meticulous prior research and risk assessment, we will be granted an environmentally safer and healthier way to produce crops en mass without fear of pests. The benefits are definitely worth the effort.

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Talking Animals – Dialogue or Vocal Mimicry?

Tatjana Dänzer

Whoever loves animals and keeps pets probably ends up talking to them at some point as if they were human companions. We like to think that our beloved furry, feathered or scaled friends understand us perfectly and respond to our speech – merely in their own characteristic language. For those who might not be too familiar with an individual pet, these sounds might be ambiguous, and one might not always tell whether food or gentle strokes are demanded. To many pet owners, it is a deep wish to have a meaningful "back and forth" conversation in a human language to understand their needs and to express their mutual feelings. Countless attempts have been made to teach all sorts of animals to learn our vocal language(s) while some species incidentally imitate man-made sounds without our direct interference. Our closest friends – cats and dogs – have developed their own specific way to communicate with their humans. Domesticated cats keep their baby language to trigger our attention and solicitude.[1] Domestic dogs have adapted some of our habits over the ages and even trained certain muscles right above their eyes. They resemble human eyebrows and help the dogs to mimic our facial expressions. This ability ensures dogs have a deep emotional bond with their humans, which is without equal in the whole animal kingdom.[2]

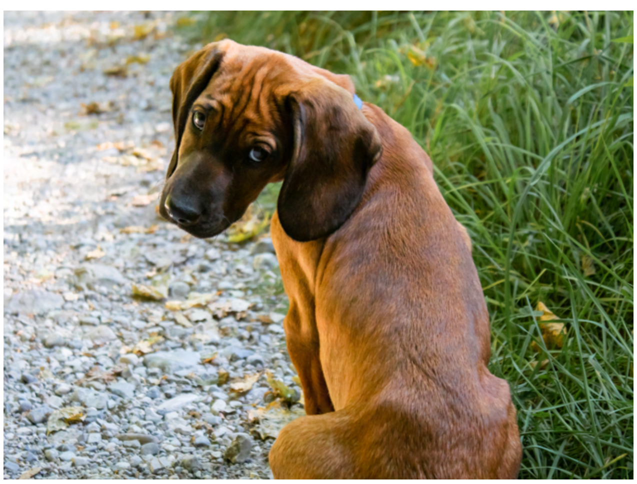

Figure 1: Dog showing his puppy-eyes, that are often interpreted as a means of pleading or innocence.[3]

Human speech is characterized by the ability of perception, interpretation, and reproduction of complex vocal sounds. To articulate a word comprehensibly, an excellent control of the vocal tract and larynx is required. Most animals are physically unable to articulate since they do not possess essential muscles, for example. Although they do not have lips and an oral cavity like ours, some birds have mastered the imitation of human sounds and even speech. The mockingbird, for example, is famous for its ability to copy any sound and sometimes fooling passersby – hence the name. The Australian lyrebird brilliantly imitates other birds as well as the sound of camera shutters and construction noises. It already has become a star on social media.[4]

Figure 2: A Northern Mockingbird (Mimus Polyglottos) as found in Canada (top) and a Lyrebird (bottom).[5,6]

Parrots are probably the most talkative birds. Due to their thick tongue and flexible membranes in their vocal organ, parrots express well-articulated words and short sentences. During their lifetime, the intelligent birds can learn several hundred words. A quick stroll around the internet will show you some hilarious videos of parrots mocking their owners or their neighbors. But is this a meaningless repetition of sounds that suit the situation by chance, or can they actually converse with their owners? Over around three decades, Irene Pepperberg studied the abilities of grey parrots. She managed to teach one of their subjects, named Alex, the name of "50 objects, 7 colors, 5 shapes and quantities up to and including six" in the English language.[7] With time, Pepperberg's parrots did not only learn words but developed cognitive capacities and a limited understanding of the relationships between certain expressions similar to that of primates.

Figure 3: The grey parrot (Psittacus Erithacus), a popular pet bird and eager (and noisy) talker.[8]

Besides birds, there are many prominent examples of mammals that have been inspired to copy some sort of speech. In 1984, Hoover, a male harbor seal at the New England Aquarium in Boston, has been reported to vocalize English words like his name, "Hello there!", "Come over here" and even human laughter.[9] As rumor has it, in the 1980s, an elephant in Kazakhstan was said to be able to make sounds that could have been understood as simple Russian and Kazakh words. But no records or scientific investigation of his talent exist. In 2012 however, a male Asian elephant in the Everland Zoo in South Korea named Koshik, was found to be able to speak five short Korean expressions. He forms the words by tucking his trunk tip into his mouth to create sounds that are identified easily by native speakers: "annyong" (hello), "anja" (sit down), "anija" (no), "nuo" (lie down), and "choa" (good). The method which Koshik is using to create sounds is highly uncommon for elephants. He must have picked up the sounds from his zookeepers and probably uses them not for conversation but as a means for social bonding with humans.[10] Dolphins usually communicate amongst their own through high-frequency sounds and clicks. But they can be taught to use their blowhole for generating sounds above the water. Experiments in the 1960s have shown that dolphins can learn to express simple syllables with this method, although disturbed by gurgling due to the swashing water.[11]

None of the examples above prove a real understanding of the words that are copied by the animals. The ability to "copy the vocalizations of another species or an environmental sound" is called heterospecific vocal mimicry.[12] It is only acquired by learning during an individual's lifetime and not by converging within generations. The motivations for such behavior are versatile and still subject to scientific studies. It might be a means to avoid conflicts, best a rival in a competition or build social relationships. In some species, vocal mimicry is mostly a male feature. Apparently, a male mating partner that is capable of learning and adapting new expressions quickly is more likely to produce likewise adaptable offspring.[13] As the examples given above suggest, animals that engage in frequent activities with humans are often prone to develop vocal mimicry without the motivation of competition or mating. But what about our closest relatives, the apes? Shouldn't they be able to communicate with us by using more than body language and a rather limited set of sounds? Early attempts on teaching chimpanzees to talk failed. The closest we got to a genuine conversation with an ape is probably sign language. Washoe was a chimpanzee lady who engaged in vivid communications with her trainer by using American Sign Langugage. When she was told about a caretaker's sickness, she showed strong sings of empathy. She even taught signs to her fellow chimpanzees.[14] A similar success was made with the gorilla lady Koko, who even adopted a cat as pet.[15] Kanzi, a male bonobo, used a lexigram for communication – a graphic catalogue of symbols representing various nouns and verbs.[16]

Figure 4: Kanzi with his sister using the lexigram.[17]

All those experiments allow us to gain deeper insights into the emotional capacity of apes and bring our species even closer together. They also show us that acquiring any kind of interspecific communication takes much longer time than teaching a toddler to speak. After all, it took us, humans, some evolutionary effort to get our brain capacity on its present level language-wise. It will take other species much longer than the span of one lifetime to transform their capabilities from vocal mimicry to vocal language. Alas, we will probably not be alive when that happens.

By the way, vocal mimicry exists in both directions. Have you ever meowed back and forth with a house cat? Try it - and please, should you both ever conduct a deep and meaningful conversation, tell us about it!

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What The Fact!?

The Journal of Unsolved Questions presents an article where one might ask "What The Fact!?" on its homepage. Set up and formulated by the members of the editorial board, or guest writers, the main purpose of the "WTF!?" consists in intriguing the reader by presenting topics of ongoing research. "WTF!?" articles published so far cover a wide variety of scientific fields, but share the feature to be of certain interest to several disciplines.
In the following, we present selected topics.

Second Wind

Mariia Filianina

All of us who have ever engaged in endurant physical activity can recall how hard it can be in the beginning. Hurting lungs, sore muscles, all these add up to the drop of energy, not to mention the willpower. Some of us can also recall that after some time of growing resentment, all of a sudden comes a boost of energy. This mysterious phenomenon is called the 'second wind'. This term was originally coined over a century ago by William James, the father of American psychology and its greatest philosopher.[1] According to James the second wind is not limited to only physical exercises, but one can feel it when engaged in any kind of demanding activity 'intellectual work, moral work, or spiritual work.'

Despite being known for a while, this phenomenon has not yet revealed its mechanism. It tuns out to be quite hard to study, i.e. to unambiguously measure physiological change associated with this, as it occurs without our deliberate planning or effort. There are a few leading scientific theories to explain the second wind (at least in relation to physical exercises) but so far, no consensus could be reached. Before we go on and explore these theories, let's look a bit deeper into what is happening when we exercise our body on a molecular level.

To perform any activity, such as muscle exercise alongside any other cellular function, our bodies require energy. An energy-carrying molecule is known as adenosine triphosphate (ATP), which together with other adenosine nucleotides is part of the energy production systems, specifically cellular metabolism.[2] ATP is created from carbohydrates, fats and proteins we consume and the body makes an ongoing supply of ATP.

The cells have different solutions for energy production, which essentially depend on the degree of physical activity. For example, a skeletal muscle at rest uses primarily fatty acids that come from body fat. There exists a special machinery in our body cells, specifically in mitochondria, which enable them to produce ATPs very efficiently. This process, however, relies on oxygen. In fact, muscles account for 50% of consumed oxygen even at rest and up to 90% during very active muscular work.[3]

In moderately active muscle, glucose is used as a fuel in addition to fatty acids. The glucose comes from the liver being produced by gluconeogenesis or by the breakdown of glycogen (glucose storage molecule). Here, again, the cell produces most of its ATP by what is called aerobic metabolism, i.e. with the help of oxygen, given that there is access to plenty of oxygen.

Now, what happens during a burst of activity, when there is suddenly not enough oxygen - the blood flow must be increased to deliver additional oxygen and nutrients, but it takes several minutes. That clearly is not fast enough to produce ATP initially.

Luckily, nature has created a way around it. After all residual ATP is rapidly consumed, another very important molecule kicks in - phosphocreatine - which is used to regenerate ATP. On the flipside is that phosphocreatine is present only in small amounts and thus can power the muscle for very short time, say sprinting for five-six seconds.

Also, the cell can use its own pool of glycogen. And these production processes do not require oxygen.

As a result, when energy is needed in a hurry, the muscle is not limited by how quickly fuel molecules can be delivered from external sources. And until that happens, the muscle operates under what is called anaerobic conditions. On the flipside here, though, is that in the absence of oxygen, fermentation must occur, the waste by-product of which is lactic acid. As a consequence, there is an accumulation of lactic acid in the blood, resulting in a drop of blood pH from 7.4 to 7.2, causing mild acidosis.[4] (This is where that nasty fatigue comes from.)

The difference in the aforementioned metabolic mechanisms can be illustrated by considering three different distance races: 100 meters, 1000 meters, and a marathon. The graph on the right hand side in Fig. 1 showing the running velocity (of the world class runners) as a function of running time illustrates an important result: the pace depends on the race duration when different fuel sources to produce ATP at different rates have to be mobilized. The rates of ATP production by different fuel sources are summarized in the table on the left hand side of Fig. 1, which also compares the total amount of ATP produced by a healthy 70-kilogram adult given that all these sources are consumed. As mentioned above, phosphocreatine is the fastest source of ATP, although this source is very limited. So, our body can have a quick but small production of ATP. On the other end is fatty acid, which produces ATP at a slow rate. But these molecules are abundant and can yield an incredible amount of ATP. In the end, it is a trade off between the production rate and the amount produced.

Fuel type	Rate, mmols/s	Total ATP
Muscle ATP		**223**
Phosphocreatine	**73.3**	**446**
Muscle glycogen (lactate fermentation)	**39.1**	**6 700**
Muscle glycogen (oxidative phosphorylation)	**16.7**	**84 000**
Liver glycogen (oxidative phosphorylation)	**6.2**	**19 000**
Fatty acids (oxidative phosphorylation)	**6.7**	**4 000 000**

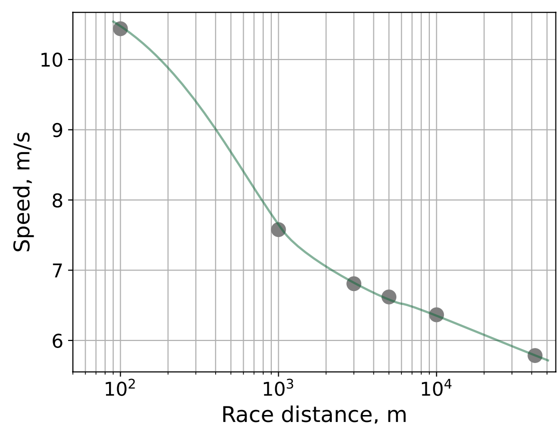

Figure 1. Rate of ATP production by different fuel sources in an average healthy individual and the total amount of ATP produced (left). Average running speed during races of different duration based on the respective world records (right).

Let's start with a 100 meter sprint, the world record for which is 9.58 seconds. During this high intensity exercise the muscles are powered by immediately available internal ATP, phosphocreatine that quickly regenerates consumed ATP and by glycolysis which is just enough to provide a short burst of energy.[5] Confirming that anaerobic metabolism is at work during a 100-meter sprint is the presence of lactate in the bloodstream of a runner right after the race.[6] Remember, accumulation of the lactic acid can be no good. So, if one were to maintain the same effort for a longer time, say run a longer distance 1000 m at the same pace, the built up of the lactic acid could cause severe damage and cell death. Thus, in a 1000 m race, internal ATP, phosphocreatine and glycolysis power the muscles only partly and the rest of energy has to come from aerobic metabolism, which is slower. This explains why the world record for a 1000 m race is only 132 seconds instead of 95 second, as one could have expected by extrapolating from a shorter distance. When it comes to much longer distances, say a marathon, the body requires ca. 150 moles of ATP,[7] which, however, cannot be supplied even if all glycogen stored in our bodies is used. Therefore, a large amount of ATP is provided by fatty acid oxidation. Now, a quick estimate based on the slow rate of ATP production (Fig. 1) from fatty acids yields that it would take six hours for the fastest runners to finish the race. Professional marathon runners, however, finish the race in just over two hours. That is because they have trained their body muscles to efficiently use both glycogen and fatty acid. Furthermore, when glycogen storage has become depleted, protein can become an important fuel, and during endurant events, protein can provide up to 10% of the energy needed for ATP resynthesis.[8,9]

Now, coming back to the second wind phenomenon. One of the existing hypotheses relies on shifting metabolic activity, i.e. that our bodies changes the type of fuel to burn while exercising. A similar switching process was observed in a rare muscle condition, known as McArdle's disease. In patients with McArdle's disease, the body cannot readily break down glycogen due to a lack of a necessary enzyme - it has to instead pull energy from alternative sources - fatty acids or proteins.[10] Individuals with McArdle's disease report experiencing very similar symptoms to second wind, while as we just discussed, in healthy individuals, this does not normally happen unless the body has run out of glycogen, e.g. due to engaging in an endurant activity, such as distance running.

Another theory finds confidence in the fact that the second wind is more widely reported by amateurs than professionals.[11] The thinking goes that after some time of physical activity, the body reaches some kind of a metabolic balance, where it acclimates enough to be able to use oxygen to its fullest potential, thus, eliminating the need to rely on anaerobic metabolism as an energy source.

As the muscles warm up and the body temperature increases slightly, the breathing is able to supply enough oxygen to meet the demand of the energy production system. Thus, at this point, what is called a steady state is established and fatigue goes away. Professional athletes are trained to perform properly from the start of the race, which can explain why they do not generally experience a second wind or they experience it much sooner. They have got their wind all along! Dr. George Sheenan, a cardiologist who used to popularize the joy and benefits of running in the 1970s, described: 'It takes 6 to 10 minutes and one degree of body temperature to shunt the blood to the working muscles. When that happens, you will experience a light warm sweat and know what the second wind mean'.[12]

On the other hand, the second wind is also hypothesised to happen due to the early release of the 'feel-good' neurochemicals[13] such as endorphins. These are naturally occurring narcotics which act in the brain to take away the pain and cause of the feeling of euphoria and wellbeing. In this sense, the second wind phenomena is believed to be closely related to the 'runners high'.[14,15] In addition to increased endorphins levels, according to the recent study done on mice, also activated during exercises cannabinoid receptors are a crucial aspect of a runner's high.[16]

Finally, second wind can as well be entirely physiological phenomenon stemming from realising one is over halfway or feeling proud to have achieved more than expected. In the end of the day, practically, is does not matter where one's second wind is coming from. Most importantly, second wind is a positive experience and one should enjoy it whenever it strikes. So that is another reason to not give up on your projects too soon, i.e. before your 'second wind' comes and helps propel across the finish line.

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