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JOELSON MORENO BRITO DE MOURA

A EVOLUÇÃO DE ESTRATÉGIAS COGNITIVAS HUMANAS PARA RESOLVER DESAFIOS DO AMBIENTE

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JOELSON MORENO BRITO DE MOURA

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Tese apresentada ao Programa de Pós-graduação em Etnobiologia e Conservação da Natureza (UFRPE, UEPB, URCA e UFPE) como parte dos requisitos para obtenção do título de doutor.

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"*Quando ouvi o astrônomo erudito,*
Quando as provas, os números foram enfileirados diante de mim,
Quando me foram mostrados os mapas e diagramas a somar, dividir e medir,
Quando, sentado, ouvia o astrônomo muito aplaudido, na sala de conferências,
Senti-me logo inexplicavelmente cansado e enfermo,
Até que me levantei e saí, parecendo sem rumo
No ar úmido e místico da noite, e repetidas vezes
Olhei em perfeito silêncio para as estrelas."

Walt Whitman

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SUMÁRIO

RESUMO 11
ABSTRACT 13
1. INTRODUÇÃO GERAL 15
1.1 - OBJETIVOS E QUESTIONAMENTO 15
1.2 – ESTRATÉGIAS DE PESQUISA 16
1.3 – ESTRUTURA DA TESE 17
2. CAPÍTULO I: FUNDAMENTAÇÃO TEÓRICA 19
2.1 – INSIGHTS TEÓRICOS DA PSICOLOGIA EVOLUCIONISTA: NOVAS OPORTUNIDADES PARA ESTUDOS EM ETNOBIOLOGIA EVOLUCIONISTA 19
Uma breve introdução à Psicologia Evolucionista 21
Conceitos Básicos da Psicologia Evolucionista 24
Modularidade da Mente 24
Natureza Humana Universal (NHU) 25
Gradualismo 26
Memória Adaptativa: Um Modelo Importante para a Etnobiologia Evolutiva 27
Insights da Memória Adaptativa para a Etnobiologia Evolutiva 32
A memória adaptativa é observada em diferentes contextos ambientais e culturais 32
A memória adaptativa funciona hierarquicamente 32
Os humanos têm uma mente naturalista universal 33
Frequência de envolvimento e experiência anterior com eventos de risco agem como potencializadores da memória adaptativa em sistemas socioecológicos 34
Considerações Finais 35
CAPÍTULO 2 37
MEMORY FOR MEDICINAL PLANTS REMAINS IN ANCIENT AND MODERN ENVIRONMENTS SUGGESTING AN EVOLVED ADAPTEDNESS 37
Abstract 38
Introduction 39
Materials and methods 43
Experiment and word selection 43
Survival scenarios 44
Participants 44
Procedure 45
Data analysis 46
Results 47

Comparison of word evaluations and the proportion of recall between environments 49
Discussion 51
Conclusion 54
Limitations and future research 54
Supporting information 55
Acknowledgments 59
References 59
CAPÍTULO 3 65
DOES THE CONGRUENCE OF INFORMATION-CONTEXT INFLUENCE THE ADAPTIVE MEMORY PERFORMANCE OF HUMAN BEINGS? AN ANALYSIS FROM THE USE OF MEDICINAL PLANTS 65
Abstract 66
1. Introduction 67
2. Material and Methods 69
2.1 Participants 69
2.2 Experiment and word selection 70
2.3 Survival scenarios 71
2.4 Procedure 72
2.5 Data analysis 73
3. Results 73
3.1 Performance of recall between lists in the robbery and survival condition 73
3.2 Performance of recall between lists in all ancestral and modern settings 77
4. Discussion 79
5. Conclusion 82
Conflict of Interest Statement 82
Acknowledgments 82
Appendix A 82
Annex 1 87
References 88
CAPÍTULO 4: CONSIDERAÇÕES FINAIS 92
4.1 PRINCIPAIS CONCLUSÕES 92
4.2 CONTRIBUIÇÕES TEÓRICAS E/OU METODOLÓGICAS DA DISSERTAÇÃO/TESE 92
4.3 PRINCIPAIS LIMITAÇÕES DO ESTUDO 93
4.4 PROPOSTAS DE INVESTIGAÇÕES FUTURAS 93
4.5 ORÇAMENTO 94
4.6 REFERÊNCIAS 94

ANEXOS 106
ANEXO 1 106
PARECER CONSUBSTANCIADO DO CEP 106
ANEXO 2 108

RESUMO

MOURA, Joelson Moreno Brito, Dr. Universidade Federal Rural de Pernambuco. Fevereiro, 2022. A evolução de estratégias cognitivas humanas para resolver desafios do ambiente. Orientador: Dr. Ulysses Paulino de Albuquerque. Coorientadores: Dr. Washington Soares Ferreira Júnior e Dra. Taline Cristina da Silva.

Durante a história evolutiva dos primeiros seres humanos, o constante contato com os recursos naturais buscando a subsistência, e as pressões seletivas recorrentes impostas pelo ambiente influenciaram o desenvolvimento de uma estrutura cognitiva chamada de *mente naturalista*. Essa estrutura cognitiva complexa foi selecionada por ajudar os hominídeos a lidar com os desafios do mundo natural e pode, dentre outras coisas, influenciar a maneira como as pessoas se relacionam com a natureza. Todavia, ainda é preciso avançar no entendimento sobre como a mente naturalista opera e quais fatores externos (ambientais) e internos (vieses da mente humana) a influenciam. Por exemplo, alguns trabalhos sugerem que a mente humana é rígida para responder a fatores relacionados a ambientes ancestrais específicos, como a savana. Mas será que isso de fato é verdade? Assim, o objetivo dessa tese é tentar entender quais vieses cognitivos influenciam o funcionamento da mente naturalista humana em ambientes ancestrais e modernos. Para isso, vamos trabalhar a partir de uma perspectiva evolutiva, utilizando o conceito de mente naturalista da etnobiologia evolutiva, e promovendo o diálogo com o campo da psicologia evolucionista, utilizando principalmente o conceito de *memória adaptativa* — que argumenta que a memória humana tem uma propensão (viés) para armazenar e recuperar na memória informações importante para sobrevivência. Assim, em um primeiro momento realizamos uma revisão de literatura para se aprofundar nos conceitos e teorias que analisam a mente humana como fruto da seleção natural, revisão esta que resultou em alguns insights teóricos. Em um segundo momento, realizamos uma pesquisa empírica com 210 voluntários, por meio de um experimento controlado, para analisar como o viés adaptativo da memória humana opera em distintos ambientes ancestrais e modernos para lidar com o desafio de usar plantas medicinais no tratamento de uma doença. Por último, realizamos um experimento, com 816 voluntários, para analisar se fatores imediatos, como a congruência entre a informação e o contexto, influenciam o desempenho da memória adaptativa em um teste de recordação. Nossos resultados evidenciaram que mente naturalista humana é flexível para lidar com desafios relacionados ao uso de plantas medicinais em diferentes contextos ambientais. Ao que tudo indica, os diferentes ambientes que os primeiros hominídeos habitaram durante a história evolutiva pode ter influenciado a evolução de uma mente flexível e sensível as demandas do

mundo natural, tanto demandas relacionadas aos ambientes ancestrais quanto a ambientes modernos. Além disso, fatores imediatos, como o efeito de congruência, podem exercer influência sobre vieses cognitivos moldados no passado ancestral — nesse caso, sobre o viés adaptativo da memória. Concluímos, portanto, que as pessoas se lembram de informações importantes para a sobrevivência independentemente do contexto ambiental em que vivem, além de que a capacidade de lembrar essas informações não está exclusivamente ligada às prioridades ancestrais.

Palavras-chave: Etnobiologia evolutiva; mente naturalista; sistema socioecológico; memória adaptativa; plantas medicinais.

ABSTRACT

MOURA, Joelson Moreno Brito, Dr. Universidade Federal Rural de Pernambuco. February 2022. The evolution of human cognitive strategies to solve environmental challenges. Orientador: Dr. Ulysses Paulino de Albuquerque. Coorientadores: Dr. Washington Soares Ferreira Júnior e Dra. Taline Cristina da Silva.

During the evolutionary history of the first human beings, the constant contact with natural resources seeking sustenance, and the recurrent selective pressures imposed by the environment, influenced the development of a cognitive structure called the naturalistic mind. This complex cognitive structure was selected to help hominids deal with the challenges of the natural world and can, among other things, influence the way people relate to nature. However, it is still necessary to advance in the understanding of how the naturalistic mind operates and which external (environmental) and internal (bias of the human mind) influence it. For example, some work suggests that the human mind is rigid to respond to factors related to specific ancestral environments, such as the savannah. But is this true? Thus, the aim of this thesis is to try to understand which cognitive biases influence the functioning of the human naturalistic mind in ancestral and modern environments. For this, we will work from an evolutionary perspective, using the concept of the naturalistic mind from evolutionary ethnobiology, and promoting a dialogue with the field of evolutionary psychology, mainly using the concept of adaptive memory — which argues that human memory has a propensity (bias) to store and retrieve important survival information in memory. So, at first, we carried out a literature review to go deeper into the concepts and theories that analyze the human mind because of natural selection, a review that resulted in some theoretical insights. In a second moment, we carried out empirical research with 210 volunteers, through a controlled experiment, to analyze how the adaptive bias of human memory operates in different ancestral and modern environments to deal with the challenge of using medicinal plants in the treatment of a disease. Finally, we carried out an experiment, with 816 volunteers, to analyze whether immediate factors, such as the congruence between information and context, influence the performance of adaptive memory in a recall test. Our results showed that the human naturalistic mind is flexible to deal with challenges related to the use of medicinal plants in different environmental contexts. Apparently, the different environments that the first hominids inhabited during evolutionary history may have influenced the evolution of a flexible mind, sensitive to the demands of the natural world, both related to ancestral environments and to modern environments. Furthermore, immediate factors, such as the congruence effect, can influence cognitive biases shaped in the ancestral past—in this case, the adaptive bias of memory. We conclude, therefore,

that people remember important information for survival regardless of the environmental context in which they live, and that the ability to remember this information is not exclusively linked to ancestral priorities.

Keywords: Evolutionary ethnobiology; naturalistic mind; socioecological system; adaptive memory; medicinal plants.

1. INTRODUÇÃO GERAL

1.1 - OBJETIVOS E QUESTIONAMENTO

No início do meu mestrado, junto com meu comitê de orientação, nos desafiamos a analisar se a preferência por paisagem na espécie humana era influenciada por vieses cognitivos moldados no ambiente de evolução ancestral. Uma vez que a Etnobiologia Evolutiva (EE) é um ramo que tenta entender a relação das pessoas com a natureza a partir de uma perspectiva evolutiva (ALBUQUERQUE & FERREIRA JÚNIOR, 2017), acreditamos que nossa pesquisa poderia contribuir para o avanço desse campo científico relativamente recente. Assim, esse empreendimento trouxe evidências tão interessantes e, consequentemente, algumas perguntas de investigação, que resolvemos dar continuidade a essa pesquisa durante o doutorado para preencher certas lacunas. Porém, ao invés de analisar a preferência por paisagem, no doutorado analisamos a memória humana, e como a maneira que armazenamos e recuperamos informações na memória pode ser influenciada pelo passado ancestral.

Nesse sentido, partimos da ideia de que durante a história evolutiva dos primeiros seres humanos, o constante contato com os recursos naturais buscando a subsistência, e as pressões seletivas recorrentes impostas pelo ambiente influenciaram o desenvolvimento de uma estrutura cognitiva, chamada *mente naturalista* (ALBUQUERQUE & FERREIRA JÚNIOR, 2017). Essa estrutura cognitiva complexa foi importante para a evolução dos hominídeos e influencia, por exemplo, a forma como as pessoas percebem e procuram compreender o mundo natural (ALBUQUERQUE & FERREIRA JÚNIOR, 2017), como a classificação dos recursos naturais. Todavia, ainda é preciso avançar no entendimento sobre como a mente naturalista opera e quais fatores externos (ambientais) e internos (vieses da mente humana) a influenciam.

A mente naturalista é um conceito chave na (EE) para entender a relação das pessoas com a natureza, e é definida como um produto da seleção natural, moldada por processos de influência recíproca como resultado da contínua relação dos seres humanos com a natureza durante o Pleistoceno, devido a importância das informações provenientes do ambiente e direcionadas à sobrevivência (ALBUQUERQUE & FERREIRA JÚNIOR, 2017). Alguns esforços iniciais foram feitos para analisar o funcionamento da mente naturalista, no qual se mostra uma estrutura cognitiva flexível que lida com desafios ambientais que acometem as pessoas recorrentemente, como doenças comuns (ver SILVA et al., 2019), e que atua em diferentes ambientes ancestrais e modernos (MOURA et al., 2021), influenciando, inclusive, a preferência por paisagem dos seres humanos (MOURA et al., 2018). A mente naturalista envolve algumas dimensões da cognição humana, como a memória e a percepção (ver ALBUQUERQUE & FERREIRA JÚNIOR, 2017). Nesse sentido, essa tese se concentra na

dimensão da memória e em seus mecanismos adaptativos para entender o funcionamento da mente naturalista.

Assim, usamos referenciais teóricos da psicologia evolucionista (PE), a qual também argumenta que a mente humana é fruto da seleção natural, que selecionou certos vieses cognitivos, ou mecanismos psicológicos evoluídos (TOOBY & COSMIDES, 1992, 2005, 2015). Um desses mecanismos, por exemplo, seria o viés adaptativo da memória, que é uma propensão para armazenar e recuperar com mais facilidade na memória informações de maior valor adaptativo e relevantes para sobrevivência (NAIRNE; THOMPSON; & PANDEIRADA, 2007). Essa vantagem mnemônica, conhecida como *memória adaptativa*, foi importante e auxiliou os hominídeos, dentre outras coisas, a evitar locais perigosos e a lembrar de locais com disponibilidade de recursos naturais — como alimento e água.

Dessa forma, o objetivo dessa tese é entender como a mente naturalista opera na espécie humana e quais fatores influenciam seu funcionamento. Para isso, partimos de uma perspectiva evolutiva baseados nos conceitos da EE — como mente naturalista — para fundamentar nossas hipóteses, promovendo um diálogo com a PE e utilizando alguns dos seus conceitos — como memória adaptativa. Por fim, pretendemos fornecer evidências sobre como a mente humana mobiliza mecanismos cognitivos para enfrentar problemas adaptativos, relacionados à sobrevivência, nos ambientes ancestrais e modernos.

1.2 – ESTRATÉGIAS DE PESQUISA

O primeiro produto da tese foi fruto de uma revisão de literatura robusta, que compôs a revisão bibliográfica. Devido a riqueza de informações que encontramos a partir da revisão de literatura nas bases de dados *Scopus* e *Web of Science*, tivemos alguns insights teóricos que podem guiar futuros estudos em etnobiologia evolutiva (ver MOURA et al., 2020). Além disso, essa revisão permitiu um diálogo entre EE e PE e ajudou a embasar a fundamentação teórica e discussão dos outros produtos da tese.

No segundo produto testamos a ideia de Nairne e colaboradores (2007) que argumentam que existe uma vantagem de processamento de sobrevivência na memória, ou seja, a memória humana é adaptada para armazenar e recuperar informações importantes para sobrevivência, principalmente se essas informações estiverem relacionadas ao contexto ancestral de evolução — como a savana africana do Pleistoceno. Todavia, uma vez que os seres humanos evoluíram em distintos ambientes ao longo da história evolutiva (ROBERTS, 2016; ZHU et al., 2018), analisamos como as pessoas recordam de informações relacionadas ao uso de plantas medicinais em ambientes ancestrais e modernos. Para isso, recrutamos voluntários e realizamos

um experimento de memória controlado com estudantes da Universidade Federal Rural de Pernambuco (UFRPE).

No terceiro capítulo, tentamos entender os fatores imediatos que influenciam os vieses evolutivos da mente humana, como a congruência entre a informação que a pessoa processa e o contexto de codificação. Por exemplo, Butler e colaboradores (2009) argumentam que algumas vantagens mnemônicas, como a promovida pelo processamento de sobrevivência (NAIRNE et al., 2007) — que é a facilidade em armazenar e recuperar na memória informações relevantes a sobrevivência —, na verdade podem refletir um efeito de congruência. Nesse caso, se uma informação fizer sentido para uma situação — como usar uma "caneta" para escrever no papel — ela será facilmente recordada em comparação com informações incongruentes — como usar "macarrão" para escrever no papel. Assim, testamos se a memória humana é influenciada pelo efeito de congruência em situações que envolvem o uso de plantas medicinais em distintos ambientes, uma vez que isso pode ajudar a entender melhor como a mente naturalista opera na relação entre pessoas e recursos naturais. Devido à pandemia da covid-19, o recrutamento e a realização da coleta de dados do terceiro capítulo foram feitos online, com a participação tanto de estudantes quanto da população no geral residente no Brasil.

1.3 – ESTRUTURA DA TESE

A presente tese está dividida em quatro capítulos. No primeiro capítulo abordamos a Fundamentação Teórica. Nesse capítulo apresentamos uma revisão de literatura e trazemos resumidamente alguns conceitos chaves da EE e da PE, promovendo o diálogo entre ambos os campos do conhecimento, na tentativa de entender melhor a mente naturalista e sua influência na maneira como as pessoas lidam com as informações do mundo natural. Além disso, trazemos alguns insights teóricos que podem servir como ponto de partida para futuras pesquisas em EE.

No segundo capítulo testamos a vantagem do processamento de sobrevivência na memória — memória adaptativa —, na tentativa de observar se existe prioridade ancestral na memória. Para isso, realizamos um experimento com estudantes voluntários da UFRPE. No experimento, cada voluntário foi convidado a ler uma lista de palavras e avaliar a relevância de cada palavra para lidar com o desafio de procurar e utilizar plantas medicinais em ambientes ancestrais — savana, floresta decidual e floresta tropical — em comparação com os ambientes modernos — cidade, deserto, tundra e floresta de coníferas. Após isso, os voluntários tentaram lembrar dessas palavras em um teste surpresa de recordação. Observamos que não há nenhuma prioridade ancestral na evocação de informações relevantes, uma vez que tanto os ambientes ancestrais quanto os modernos mostraram uma evocação semelhante de informações relevantes.

Isso sugere que o aparato cognitivo evoluído permite que os seres humanos sobrevivam e possam criar estratégias de sobrevivência para enfrentar os desafios impostos em vários ambientes. Assim, trazemos evidência que a mente naturalista humana opera por meio de um mecanismo cognitivo flexível, que reflete, por exemplo, os diferentes ambientes em que habitaram os primeiros hominídeos.

No terceiro capítulo, buscamos entender se o desempenho da memória adaptativa é influenciado por fatores imediatos, como a congruência entre informação e o contexto. Esse *efeito de congruência* se refere ao aperfeiçoamento do desempenho da memória quando o contexto de codificação — que são situações simuladas envolvendo determinado desafio — e a palavra a ser lembrada são compatíveis, formando a unidade integrada palavra-contexto — por exemplo, a palavra "leão" se encaixa no ambiente de savana e tende a ser mais bem lembrada em comparação com a palavra "tubarão" que não se encaixa nesse mesmo contexto. Devido à pandemia, o recrutamento dos voluntários e o experimento foi feito online, utilizando um ambiente virtual desenvolvido pela empresa *Quacks Interatividade Digital* (www.quacks.com.br). Neste estudo, controlamos a congruência das palavras, e simulamos cenários ancestrais e modernos em que cada voluntário avaliou a relevância de informações para realizar a tarefa de encontrar e usar plantas medicinais, além de uma situação controle que envolvia um assalto a banco, para em seguida os voluntários lembrarem dessas palavras em um teste surpresa de recordação. Nossos resultados sugerem que a congruência informação-contexto é um fator importante que potencializa o desempenho mnemônico em ambientes ancestrais e modernos. Assim, a memória humana pode operar de maneira sensível aos estímulos e flexível ao gerar respostas adaptativas de acordo com a demanda do ambiente.

Por fim, no quarto capítulo trazemos as principais conclusões da tese e elucidamos suas limitações. Mostramos como as evidências que encontramos, em conjunto e de maneira integrada, ajudam a entender o papel dos vises cognitivos que precedem o comportamento humano na maneira como as pessoas se relacionam com a natureza. A mente naturalista humana é flexível e sensível aos desafios do ambiente, não estando presa a um único ambiente ou situação específica. Essa flexibilidade foi e continua sendo importante para nos adaptarmos as várias situações desafiadoras existentes no mundo natural.

2. CAPÍTULO I: FUNDAMENTAÇÃO TEÓRICA

2.1 – INSIGHTS TEÓRICOS DA PSICOLOGIA EVOLUCIONISTA: NOVAS OPORTUNIDADES PARA ESTUDOS EM ETNOBIOLOGIA EVOLUCIONISTA[1]

Durante sua história evolutiva, os humanos tiveram que interagir com seu meio ambiente, tanto para capturar recursos quanto para evitar ameaças. Essa interação, estudada por diversos campos científicos, pode ter influenciado fortemente a evolução dos hominídeos, de modo que a relação entre as pessoas e a natureza pode ser mediada por vieses e comportamentos moldados no passado evolutivo (ver ALBUQUERQUE; FERREIRA JÚNIOR, 2017).

Nesse sentido, um campo interdisciplinar recentemente desenvolvido denominado Etnobiologia Evolutiva (EE) está preocupado em compreender como os processos ecológicos e evolutivos influenciam a cognição e o comportamento das pessoas em relação aos seus ambientes (ALBUQUERQUE et al., 2015). Para isso, a EE promove a integração e sistematização de conceitos evolutivos vindos da Evolução Cultural, Genética, Psicologia Evolucionista (PE) entre outros (ALBUQUERQUE; FERREIRA JÚNIOR, 2017). No entanto, essa integração é recente e pouco se sabe sobre como os vieses evolutivos podem operar na dinâmica relação entre os humanos e a natureza. A premissa básica da EE é que pressões seletivas durante a evolução humana, associadas à necessidade de se relacionar com o meio ambiente para sobreviver, geraram nos humanos uma mente naturalista, que envolve uma estrutura cognitiva complexa que influencia a maneira como as pessoas percebem e buscam compreender o mundo natural (ALBUQUERQUE; FERREIRA JÚNIOR, 2017). Assim, acreditamos que os estudos etnobiológicos que não consideram os vieses evolutivos em suas hipóteses podem deixar de captar um determinado fenômeno de maneira completa.

Um exemplo prático pode ser a coleta de dados em estudos etnobiológicos. Para Albuquerque e Ferreira Júnior (2017), os estudos etnobiológicos que coletam dados empíricos em sistemas reais estão, na verdade, recuperando dados armazenados em memórias individuais, e poucos estudos em etnobiologia reconhecem a memória como um viés na coleta de dados. Assim, um elemento chave é entender como a memória pode influenciar a coleta e interpretação das informações obtidas em sistemas socioecológicos[2]. Nesse ponto, o conceito de memória

[1] Esse tópico originou um artigo, publicado online em 29 de janeiro de 2020, na revista Evolutionary Biology, com o título "Theoretical Insights of Evolutionary Psychology: New Opportunities for Studies in Evolutionary Ethnobiology" (versão do artigo publicado no Anexo 2, doi.org/10.1007/s11692-020-09491-0).

[2] Os sistemas socioecológicos representam um produto da interação entre os sistemas socioculturais — o conjunto de crenças, conhecimentos e comportamentos em grupos humanos — e os sistemas ecológicos — o ambiente biótico e abiótico de grupos humanos (Berkes e Folke 2000).

adaptativa abordado na PE parece ser fundamental, uma vez que assume que os humanos tendem a priorizar na memória informações de maior valor adaptativo que são relevantes para a sobrevivência (NAIRNE et al., 2007). Se isso for verdade, é imprescindível que os estudos etnobiológicos considerem os mecanismos de memória moldados no passado evolutivo em suas coletas de dados, uma vez que, por exemplo, recursos medicinais muito lembrados por indivíduos de uma determinada comunidade podem conter características terapêuticas vantajosas para a sobrevivência.

Além disso, em um estudo recente Silva et al. (2019) observaram que a mente humana tende a lembrar de informações sobre doenças frequentes ou quando estão relacionadas a experiências anteriores do indivíduo com determinada doença. Considerando o contexto ancestral, isso pode refletir adaptações que foram importantes para a sobrevivência dos hominídeos — ajudando-os a se lembrar, por exemplo, de lugares perigosos ou da localização de alimentos e água — e que persistem até hoje em populações humanas (ver NAIRNE et al., 2007).

Embora acreditemos que os humanos herdaram geneticamente tendências comportamentais moldadas por seu passado ancestral, essas tendências podem ser modificadas, expressas ou silenciadas de acordo com o contexto ambiental (ver BARRETT, 2012). No entanto, essa herança genética não pode ser ignorada e parece preceder o comportamento. Por exemplo, para que a complexidade comportamental das sociedades humanas surja e aumente ao longo do tempo, certas faculdades mentais inatas, geneticamente selecionadas em algum ambiente ancestral, devem estar presentes — como a capacidade de imitar — tornando a evolução cultural[3] possível (ver STANFORD, 2019). Portanto, parece crucial investigar os aspectos evolutivos por trás das decisões e do comportamento dos humanos em relação à natureza. Por isso, a PE se mostra promissora para nosso entendimento dos mecanismos que operam nessa relação.

Assim, o principal objetivo deste capítulo é demonstrar como os pressupostos da PE podem nos ajudar a entender a complexa e dinâmica relação das pessoas e seus ambientes, e particularmente o que influencia suas decisões. Isso só é possível entendendo as raízes evolutivas que precedem o comportamento. Para tanto, apresentamos o cenário teórico da PE e suas aplicações para estudos na área da EE. Primeiramente, apresentamos e descrevemos os principais conceitos da PE. Em seguida, explicamos o conceito de memória adaptativa (um

[3] Evolução Cultural é um campo científico que analisa as mudanças detectadas nas sociedades sob a perspectiva da teoria da evolução darwiniana, e que leva em consideração aspectos como variação, competição e herança (Mesoudi 2011, 2016).

conceito importante) e como a testamos empiricamente. Por fim, trazemos insights e exemplos que podem nortear futuros estudos que busquem usar uma perspectiva evolutiva para compreender a relação entre as pessoas e a biota. Esse primeiro esforço teórico pode ajudar a promover uma integração produtiva com a EE.

Uma breve introdução à Psicologia Evolucionista

A psicologia evolucionista está preocupada em compreender o funcionamento da mente humana, analisando-a como um produto da seleção natural (BUSS, 1990; BREYER, 2015). Portanto, é uma abordagem funcionalista — ela investiga as funções da mente. A tendência teórica que mais influenciou a PE foi a Sociobiologia. Segundo Wilson (1975), criador desse campo científico, a Sociobiologia pode ser definida como o estudo sistemático das bases biológicas do comportamento animal. Desde a sua concepção, a Sociobiologia objetivou criar modelos padronizados para entender o comportamento animal de uma perspectiva evolutiva e expandiu esse plano para o comportamento social; em contraste, a PE é conhecida por ser projetada para compreender exclusivamente os mecanismos psicológicos que precedem o comportamento humano (ver BREYER, 2015). Os psicólogos evolucionistas criticaram o descaso da sociobiologia com os mecanismos psicológicos moldados nos paleoambientes, e por isso propuseram outro nível de explicação para a natureza humana, dando menos atenção ao comportamento humano e focando nas adaptações que permitem sua expressão, neste caso, os mecanismos psicológicos evoluídos (HATTORI; YAMAMOTO, 2012).

Embora a sociobiologia e a PE compartilhem da visão de que os seres humanos evoluíram por meio do processo de seleção natural, os dois domínios diferem em alguns aspectos fundamentais. Por exemplo, de acordo com Buss (1990, 1995), na sociobiologia os humanos desenvolveram adaptações que sempre visam maximizar sua aptidão inclusiva — a capacidade de, além de deixar descendentes férteis, o indivíduo também tem cuidado parental, uma vez que seus parentes também carregam cópias de seus genes. Por outro lado, na PE não existe maximização do fitness porque, em princípio, a seleção natural não teria criado mecanismos que direcionassem os seres humanos a viver com o propósito de deixar descendentes em qualquer situação. Alguns psicólogos evolucionistas chamam essa ideia de "falácia sociobiológica" (BUSS, 1990). Assim, para muitos estudiosos, a PE é um tipo de sociobiologia, porém menos polêmica por ser menos determinista, uma vez que as adaptações mentais moldadas pela seleção natural podem ser expressas ou não no ambiente atual (ver BUSS 1990).

A PE busca explicações a partir das pressões que moldaram a mente humana no passado evolutivo para resolver problemas específicos relacionados com a sobrevivência e reprodução das espécies. Nesse sentido, a PE representa um cenário teórico que integra aspectos da evolução cognitiva, a ideia de que o cérebro é um processador de informações do meio ambiente, e está relacionada com a biologia evolutiva, pois defende que assim como outros órgãos do corpo humano, o cérebro também foi alvo da seleção natural e moldado para processar um conjunto de informações do meio ambiente em detrimento de outras (TOOBY; COSMIDES 1992). A PE é um campo científico relativamente recente, surgindo no início do século XX e ganhando visibilidade nas décadas de 1970 e 1980.

Embora a PE seja uma disciplina acadêmica relativamente nova, as abordagens funcionalistas em psicologia são antigas, como no caso da psicologia funcional, criada por William James no final do século 19, embora não tenha desenvolvido uma base teórica sólida (GANGESTAD; TYBUR 2016). O desenvolvimento da PE se deu por um grupo de pesquisadores que iniciaram uma série de estudos teóricos e empíricos (COSMIDES; TOOBY 1987; SYMONS; 1987; BUSS 1989; COSMIDES 1989; BARKOW et al., 1992) a fim de compreender a natureza e o funcionamento da mente humana, principalmente em relação a preferências humanas na seleção de parceiros. Entre os autores que mais contribuíram para a popularização e expansão da PE, podemos citar Leda Cosmides, John Tooby, Donald Symons, Jerome Barkow e David Buss.

Desde então, a PE vem ganhando progressivamente a atenção de importantes áreas científicas que analisam a evolução do comportamento humano. O campo da ciência política, por exemplo, publicou estudos sobre como as opiniões políticas das pessoas podem ser afetadas por comportamentos ligados ao passado ancestral (ver EDWARDS, 2003; BROWN, 2013; KUBINSKIA et al., 2018; PETERSEN, 2018). A área de marketing também trouxe resultados empíricos interessantes sobre como os padrões de consumo humano são influenciados por fatores evolutivos (ver SAAD; GILL 2000; HARTMANN; APAOLAZA-IBÁÑES, 2010, 2013; HASFORD et al., 2018). A tabela 1 mostra alguns campos de interesse de pesquisa em PE. Na tabela 1 mostramos alguns campos de interesse das pesquisas em PE.

Tabela 1: Alguns campos de interesse da psicologia evolucionista.

Campos de interesse	**Finalidade**	**Algumas publicações**
Cognição e comportamento humano	Entender os fatores que influenciam a evolução da cognição e do comportamento humano	Stevenson et al., 2014; Roberts, 2015; Roos et al., 2016; Ferera *et al*. 2018; Wilke e Todd, 2018.

Comportamento religioso	Compreender a influência da seleção natural sobre o comportamento religioso.	Boyer e Bergstrom, 2008; Leathers e Raines, 2014; Franek, 2016; Smail, 2018.
Teoria Política	Entender os processos político nas sociedades	Edwards, 2003; Brown, 2013; Kubinskia et al., 2018; Petersen, 2018.
Evolução da Arte	Compreender o papel da arte na história evolutiva dos seres humanos.	Sugiyama, 1996; Hagen e Bryant, 2003; Honing e Ploeger, 2012; Sütterlin et al., 2014.
Economia	Analisar a evolução da lógica econômica dos seres humanos	Hoffman et al., 1998; Li et al., 2012; Lawrence e Pirson, 2015; King, 2018.
Preferências humanas	Analisar como o passado evolutivo moldou as preferências dos seres humanos. Por exemplo, preferência por paisagem e objetos.	Balling e Falk, 1982; Orians e Heerwagen, 1992; Li et al., 2013; Altman et al., 2016; Bøggild e Laustsen, 2016; Townsend e Barton, 2018.
Marketing	Identificar padrões de consumo dos seres humanos.	Holbrook e O'Shaughnessy, 1984; Saad e Gill, 2000; Hartmann e Apaolaza-Ibáñes, 2010, 2013; Hasford et al., 2018.
Seleção sexual e diferenças de sexo	Compreender a influência da diferença de sexo na seleção de companheiros.	Buss et al., 1992; Buss e Schmitt, 1993; Schwarz e Hassebrauck, 2012; Conroy-Beam e Buss, 2018; DeLecce et al., 2017; Jeffery et al., 2018.
Emoções humanas	Entender como a seleção natural moldou as emoções ao longo do tempo.	Tooby e Cosmides, 1990; Al-Shawaf, 2016; Klasios, 2016; Eisend, 2018.

Os estudos em PE baseiam-se na premissa essencial de que muitos mecanismos psicológicos humanos evoluíram como resultado das pressões seletivas a que os hominídeos foram submetidos no Pleistoceno (BUSS, 1995). Semelhante aos outros órgãos do corpo humano, os mecanismos subjacentes de processamento de informações localizados no cérebro são adaptações biológicas que permitiram a sobrevivência e reprodução dos primeiros hominídeos (BUSS, 1990; KLASIOS, 2016). Assim, a mente humana funciona de forma semelhante a um sistema computacional, projetado pela seleção natural para resolver problemas adaptativos enfrentados por nossos ancestrais (TOOBY; COSMIDES, 2015), e que devido a

isso os humanos se comportam de forma adaptativa (KLASIOS, 2016). Essa perspectiva evolutiva foi uma grande novidade para os pesquisadores em psicologia que anteriormente tentavam compreender o comportamento humano comumente influenciado apenas pelo contexto histórico e social atual. No entanto, essa nova abordagem gerou certa confusão teórica devido à sua semelhança com a sociobiologia e, especialmente, com o conceito de modularidade da mente (consulte a próxima seção) (TOWNSEND; BARTON, 2018).

Com base nessas premissas, foram criados alguns conceitos essenciais que conduzem a maioria das pesquisas em PE (ver BOLHUIS et al., 2011), que serão resumidos na próxima sessão. É importante notar que esses conceitos são, em certa medida, criticados por alguns cientistas. Assim, também descrevemos algumas dessas críticas e visões alternativas.

Conceitos Básicos da Psicologia Evolucionista

Assumir que os humanos se comportam de forma adaptativa só faz sentido se assumirmos que houve um ou mais ambientes que promoveram tais adaptações. Assim, o conceito de Ambiente de Adaptabilidade Evolutiva (AAE) argumenta que nossos mecanismos psicológicos evoluíram em resposta às características estáveis presentes nos AAE (TOOBY; COSMIDES, 2015), por exemplo, em ambientes de savana africana e floresta tropical do Pleistoceno. No entanto, a primeira versão desse conceito foi amplamente criticada, uma vez que apenas a savana era considerada um AAE (ver BOLHUIS et al., 2011). O conceito recente de AAE é amplo e menos específico, pois considera todos os ambientes seletivos relevantes do passado ancestral (ver TOOBY; COSMIDES, 2015).

Assim, o AAE não se limita apenas à savana africana do Pleistoceno (ver TOOBY; COSMIDES, 2015). Nesse sentido, os hominídeos podem ter desenvolvido mecanismos psicológicos em diferentes ambientes durante sua evolução no Pleistoceno, em um período anterior ou depois de seu assentamento na savana (ver HARTMANN; APAOLAZA-IBÁÑES, 2010; MOURA et al., 2018).

Modularidade da Mente

A mente humana consiste em módulos de domínio específicos que evoluíram para resolver problemas adaptativos distintos que surgiram no passado ancestral (TOOBY; COSMIDES, 2015). Por exemplo, módulos ligados à detecção de trapaceiros, cooperação,

identificação e fuga de predadores, entre outros. De acordo com Townsend e Barton (2018), herdamos os módulos específicos de nossos ancestrais. Por exemplo, era extremamente importante para os primeiros hominídeos identificar e evitar animais peçonhentos, como serpentes e aranhas, para que, com o tempo, a seleção natural favorecesse indivíduos capazes de detectar tais ameaças. Isso pode explicar até mesmo o comportamento atual da fobia dos humanos em relação a esses animais (para um argumento mais completo, consulte TOOBY; COSMIDES, 2015). Além disso, a capacidade de memorizar informações que ajudam a sobreviver em ambientes semelhantes à savana do Pleistoceno parece ser um mecanismo psicológico de extrema importância (ver NAIRNE et al., 2007).

Outros mecanismos psicológicos documentados na literatura são: reconhecimento facial de parentes, atração sexual por parceiros que demonstram gentileza e inteligência, detecção de trapaceiros em situações cotidianas, possível preferência por ambientes semelhantes à savana, entre outros (ver BUSS, 1995; TOOBY; COSMIDES, 2015; TOWNSEND; BARTON, 2018). No entanto, entre os conceitos da psicologia, este é o mais controverso.

De acordo com Bolhuis et al. (2011), há evidências da neurociência que não corroboram a existência da modularidade. Por exemplo, há evidências de que os animais aprendem e estabelecem relações causais entre uma ampla variedade de eventos, e isso só é possível se a mente não for modular (ver BOLHUIS et al., 2011). Existe uma ampla conexão das várias estruturas neurais em vários processos psicológicos (BOLHUIS et al., 2011). Assim, a mente humana pode trabalhar por meio de procedimentos cognitivos mais gerais, o que permite o aprendizado e a resolução de problemas em diferentes condições ambientais e sociais (ver BOLHUIS et al., 2011). Além disso, Barrett (2012) argumenta que a mente pode ser composta por módulos gerais e específicos. Nesse caso, as adaptações do cérebro são flexíveis e podem integrar, por exemplo, mecanismos moldados nos paleoambientes com mecanismos construídos durante o desenvolvimento ontogenético do indivíduo (ver BARRETT, 2012).

Natureza Humana Universal (NHU)

A PE assume que os mecanismos psicológicos evoluídos da mente humana são responsáveis por produzir uma NHU, ou seja, uma "espécie típica" (TOOBY; COSMIDES, 2015). Essa característica do ser humano é expressa por meio de diferentes condições ambientais e sociais (ver TOOBY; COSMIDES, 2015). Nesse sentido, o principal objetivo de longo prazo da PE é o mapeamento desta NHU (TOOBY; COSMIDES, 2015). No entanto, a principal crítica em relação ao conceito de NHU é o fato de que os comportamentos observados

em populações humanas específicas são generalizados para todas as populações (ver BOLHUIS et al., 2011). Por exemplo, muitos estudos em PE são realizados com estudantes universitários, considerados uma amostra representativa da natureza humana (ver BOLHUIS et al., 2011). Neste caso, o universalismo ignora aspectos do desenvolvimento ontogenético, uma vez que o ambiente irá evocar respostas geneticamente pré-determinadas (BOLHUIS et al., 2011).

Ao investigar a evolução da natureza humana, é importante integrar conceitos e teorias, como a Epigenética e a Teoria da Construção de Nicho, que entendem os seres humanos como construtores ativos de seus ambientes. Nesse sentido, devido à diversidade de condições ambientais, a interação pessoa-ambiente pode ter gerado respostas adaptativas distintas entre os seres humanos durante a história evolutiva (ver LALAND; BROWN 2006; BOLHUIS et al., 2011).

Gradualismo

A mente humana possui um conjunto de genes coadaptados ao ambiente ancestral que não respondem rapidamente às pressões seletivas do ambiente atual (TOOBY; COSMIDES 2005, 2015). Os processos evolutivos são lentos e precisam de centenas de gerações para construir um programa "mental" altamente complexo. Nesse sentido, as mentes humanas ainda estariam adaptadas ao mundo de nossos ancestrais (TOOBY; COSMIDES, 2015). As pessoas geralmente experimentam um atraso adaptativo ao enfrentar os desafios das sociedades industrializadas, porque esses ambientes são diferentes do ambiente em que evoluímos. Por exemplo, o gosto por alimentos gordurosos é um comportamento adaptativo para ambientes ancestrais, nos quais a gordura era escassa, mas não é adaptativo no ambiente atual porque aumenta a incidência de doenças cardiovasculares (COSMIDES; TOOBY, 2003). No entanto, há evidências recentes de mudanças genéticas importantes em populações humanas que contradizem o gradualismo (BOLHUIS et al., 2011).

Talvez uma das maiores fragilidades da PE seja o fato de não levar em consideração até que ponto as atividades humanas podem acelerar a evolução biológica, modificando ou silenciando certas predisposições herdadas geneticamente (ver STANFORD, 2019). Por exemplo, a inclinação para favorecer ambientes abertos como a savana proposta por alguns estudos de PE não é mais observada em algumas culturas, o que pode resultar do estabelecimento dos seres humanos em diferentes ambientes modernos (ver MOURA et al., 2017, 2018). Além disso, há evidências de que práticas culturais podem ter influenciado a evolução humana, alterando as pressões seletivas, resultando na seleção de genes específicos.

Um exemplo seria o aumento ao longo do tempo da frequência do gene *CD72* e de outros genes que melhoram a resistência à malária na África Ocidental, como resultado da adoção da agricultura, que expôs as populações desta região a esta doença (ver LALAND et al., 2010; SANTORO et al., 2017). Dessa forma, a interação entre genes e cultura tem alguma influência na história evolutiva dos humanos (LALAND et al., 2010).

De acordo com Laland e Brow (2006), o ser humano tem a capacidade de modificar o meio ambiente, ou seja, modifica o meio em que vive para se adequar e com isso reduz o atraso adaptativo. Esses autores argumentam que existe uma complementaridade adaptativa do organismo e do meio ambiente, com uma interação dinâmica entre a seleção natural e a construção de nichos culturais. Nesse caso, mesmo que o ser humano seja afetado por doenças cardiovasculares, ele tem a capacidade de construir hospitais ou remédios para lidar com essas doenças (para um argumento mais completo, ver LALAND; BROWN, 2006).

Memória Adaptativa: Um Modelo Importante para a Etnobiologia Evolutiva

Com base na perspectiva da psicologia evolucionista, em que a mente humana evoluiu para favorecer informações específicas para lidar com as ameaças dos ambientes ancestrais (TOOBY; COSMIDES, 2015), o modelo de memória adaptativa proposto por Nairne e colaboradores (2007) descreve o comportamento diferencial da mente humana em uma situação de sobrevivência, sugerindo que nosso sistema de memória evoluiu por meio da seleção natural para priorizar informações que são relevantes para a sobrevivência e reprodução. Segundo Nairne e Pandeirada (2008), essa propensão da mente humana para favorecer esse tipo de informação originou-se em decorrência das pressões seletivas dos ambientes ancestrais e pode ter sido de extrema relevância para os primeiros hominídeos recordarem informações como locais de alimentação, ação de predadores e comportamento de potenciais parceiros.

O experimento de Nairne e colaboradores (2007) mostrou que quando as pessoas são solicitadas a se imaginarem presas em um ambiente semelhante a uma "savana africana do Pleistoceno" sem suprimentos básicos de sobrevivência, como água e comida, e tendo que evitar predadores, elas tendem a lembrar melhor de palavras que seriam relevantes para lidar com esse cenário de sobrevivência em relação a outros cenários menos críticos, como o cenário de "mudança para um ambiente estrangeiro".

Desde então, o comportamento da mente humana para priorizar informações relevantes a sobrevivência tem sido consistentemente debatido em um corpo emergente de estudos (ver NAIRNE et al., 2007; NAIRNE et al. 2008; NAIRNE; PANDEIRADA, 2008; NAIRNE et al.,

2009; NAIRNE et al., 2012; SEITZ et al., 2018), no qual várias investigações replicaram as descobertas de Nairne e colegas (WEINSTEIN et al., 2008; SANDRY et al., 2013; YANG et al., 2014), e essas investigações foram realizadas com pessoas de diferentes faixas etárias (NOUCHI, 2012; PROKOP; FANČOVIČOVÁ, 2014; BROESCH et al., 2014), ou que vivem em contextos ambientais diferentes (BARRETT; BROESCH, 2012; PROKOP; FANČOVIČOVÁ, 2014).

Por exemplo, ao estudar a recordação de animais perigosos e não perigosos, Barrett e Broesch (2012) descobriram que crianças que moram na cidade de Los Angeles, na Califórnia (Estados Unidos) e crianças em uma aldeia Shuar na Amazônia equatoriana apresentaram altos níveis de recordação quando imagens e informações sobre o nome e a dieta de animais perigosos foram apresentadas. Esse resultado sugere que a propensão humana para recordar informações importantes para sobrevivência pode ser inata em nossa espécie e, independentemente do contexto ambiental em que as pessoas vivem, há uma tendência da memória humana em priorizar essas informações em detrimento de quaisquer outras.

Outro aspecto interessante que tem causado controvérsia entre alguns psicólogos evolucionistas é o fato de alguns estudos defenderem a ideia de que a capacidade humana de recordar essas informações não está necessariamente ligada a situações que se referem a ameaças de ambientes ancestrais. Yang e colaboradores (2014) observaram, por exemplo, que palavras importantes a sobrevivência eram bem lembradas pelas pessoas tanto em cenários de sobrevivência ancestrais (pastagens) quanto em ambientes não ancestrais/modernos (montanhas). Além disso, Young e colaboradores (2012) ao testar a atenção humana direcionada a ameaças, notaram que as ameaças de ambientes modernos — como armas de fogo e carros — também capturam e mantêm a atenção da mesma forma que seria esperado para ameaças de ambientes ancestrais — como cobras e aranhas. Isso sugere que a capacidade humana de recordar informações adaptativas — ameaças que podem comprometer a sobrevivência e reprodução humana — também pode ser observada em pessoas que ocupam contextos ambientais distintos, independentemente de essas informações estarem associadas a uma ameaça de ambiente ancestral — savana africana do Pleistoceno — em oposição ao que alguns psicólogos evolucionistas ainda sugerem. O que é interessante nesses achados é que eles mostram que, embora haja adaptações cognitivas resultantes de pressões seletivas, elas não são programadas para responder apenas a ameaças ancestrais. Isso pode estar relacionado à capacidade humana de responder de forma adaptativa a situações que podem comprometer sua sobrevivência (por exemplo, ver estudo de SILVA et al. 2019).

Com base nessa perspectiva, Nouchi (2012), ao comparar o efeito da sobrevivência na memória de jovens e idosos, observou que ao classificar as palavras em situação de sobrevivência e autorreferência — o que incentiva os participantes a recuperar explicitamente memórias pessoais episódicas — os participantes tenderam a relembrar uma maior quantidade de estímulos vinculados à situação de sobrevivência. De acordo com Wixted e colaboradores (2018), as memórias episódicas correspondem à lembrança de experiências individuais passadas que ocorreram em um determinado tempo e lugar. Este fato é interessante, visto que o estudo de Nouchi (2012) revela que a evocação de informações relacionadas a experiências pessoais passadas não recebeu uma melhor evocação das pessoas; pelo contrário, houve uma tendência a recordar informações associadas a um contexto de sobrevivência.

Esses resultados revelam alguns insights interessantes quando comparados com outros achados. Estudos empíricos mostraram que experiências pessoais passadas com catástrofes ambientais, por exemplo inundações, tendem a receber mais atenção na memória das pessoas (ver RUIN et al., 2007), o que nos leva a pensar que as memórias episódicas são intensificadas apenas em situações críticas que envolvem a sobrevivência. Sousa e colaboradores (2016), por exemplo, ao realizarem um estudo em uma comunidade rural localizada no Nordeste do Brasil, observaram que as pessoas tendem a priorizar na memória informações sobre as plantas medicinais utilizadas no último ano, que também são apontadas como as mais importantes. Nesse caso, priorizar na memória recursos importantes no uso medicinal vinculado a experiências anteriores recentes pode favorecer a sobrevivência das pessoas ao lidar com doenças.

Outro aspecto importante é que a memória humana parece se comportar de forma diferente quando confrontada com informações relevantes para o cuidado com a saúde. Por exemplo, Alqahtani e colaboradores (2017) descobriram que doenças infecciosas emergentes, nas quais as pessoas eram mais suscetíveis, como a síndrome respiratória do Oriente Médio, recebiam mais atenção na memória das pessoas do que as catástrofes em massa que ocorreram recentemente nessa população.

Em outro estudo, Prokop e colaboradores (2014) observaram que informações sobre doenças parasitárias consideradas de relevância adaptativa para humanos eram mais lembradas do que informações sobre hormônios, que eram consideradas informações irrelevantes em uma situação de sobrevivência. Além disso, Fernandes e colaboradores (2017) observaram que pessoas adultas têm uma melhor recordação de objetos que foram descritos como sendo tocados por pessoas com doenças graves — transmissíveis ou letais — em detrimento de itens descritos como tocados por pessoas saudáveis. Isso sugere que a memória humana pode ter um

desempenho melhor quando são apresentadas informações relevantes para os cuidados com a saúde. Curiosamente, a mesma informação parece emergir na lembrança quando outras informações relacionadas à sobrevivência estão sendo apresentadas simultaneamente (ver ALQAHTANI et al., 2017).

Além disso, nota-se que, à medida que o ser humano se depara com informações adaptativas relacionadas ao mundo natural, a memória também parece se comportar de forma diferente. Por exemplo, Prokop e Fančovičová (2014) verificaram que crianças quando expostas a informações de plantas tóxicas e não tóxicas associadas a imagens de frutos de distintas colorações que remetiam a essas plantas — vermelhos e pretos = plantas tóxicas e verdes = plantas não tóxicas —, as informações de plantas com frutos de coloração preta foi melhor recordada pelas crianças devido a associação com frutos tóxicos. Barrett e colaboradores (2016) também observaram que crianças de diferentes culturas lembravam melhor de informações sobre animais perigosos, seguidas de alimentos e objetos perigosos. Esses resultados também podem indicar que o desempenho da memória humana é melhor quando exposta a certas informações sobre o mundo natural.

Esses achados parecem ser consistentes com a ideia de uma hierarquização da memória proposta por Sandry e colaboradores (2013). Esses autores estudaram a memorização de palavras em diferentes cenários relacionados a mecanismos adaptativos — sobrevivência, medo e fobia, seleção de parceiros, evitar incesto, detecção de trapaceiros, ciúme, infidelidade e ganhar ou manter status — e observaram que o cenário de sobrevivência se sobressaiu em recordação de palavras frente a todas as outras informações também adaptativas. A explicação encontrada por Sandry e colaboradores (2013) para esse resultado é que isso ocorre porque o cenário de sobrevivência apresenta uma estrutura mais geral, ou seja, consegue invocar todos esses mecanismos adaptativos simultaneamente, e como consequência consegue ativar maiores áreas do cérebro associados a memória, ao invés de um único mecanismo adaptativo de forma isolada — por exemplo, apenas fobia. Portanto, é provável que a memória humana funcione de forma hierárquica durante a recordação de informações adaptativas, ou seja, que a memória não retenha de forma igual essas informações. Dessa forma, se a memória humana fosse um sistema rígido para a priorização dessas informações, seria esperado que todas elas recebessem igual recordação.

Neste caso, seria esperado que no estudo de Barret, Peterson e Frankenhuis (2016), por exemplo, as pessoas lembrassem de forma igual informações sobre animais, alimentos e objetos perigosos, visto que todas essas informações eram adaptativas. No entanto, como foi observado pelos autores, as pessoas tendiam a lembrar melhor as informações associadas aos animais

perigosos do que informações sobre alimentos e objetos perigosos. Isso pode estar acontecendo, como sugere Sandry e colaboradores (2013), porque algumas dessas informações adaptativas, por algum motivo ainda desconhecido, podem estar intensificando a recordação de algumas dessas informações melhores do que outras. Além disso, um insight relevante obtido a partir dos achados de Barret e colaboradores (2016), é que talvez a memória humana opere de forma distinta quando confrontada com informações sobre o mundo natural, e tenha um menor desempenho quando as informações adaptativas apresentadas estejam dissociadas desse contexto.

Assim, é provável que a memória humana funcione hierarquicamente para lembrar esse tipo de informação (figura 1), e tenha um desempenho diferente quando essa informação envolve as adversidades de ambientes naturais. Isso nos leva à ideia da existência de uma *mente naturalista humana*, capaz de lembrar melhor essa informação em detrimento de quaisquer outras. Esse comportamento da memória pode ser observado em diversos contextos ambientais modernos e em diferentes culturas.

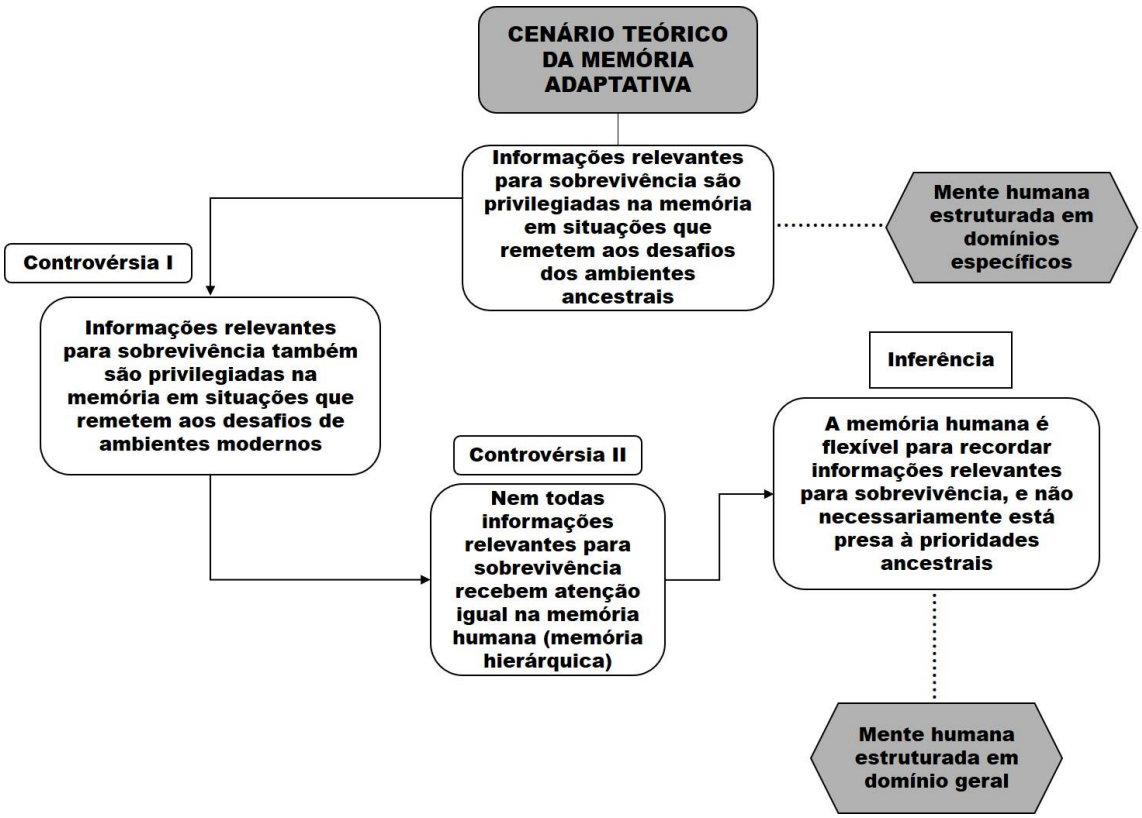

Figura 1: Cenário teórico da memória adaptativa, controvérsias e possíveis inferências.

Insights da Memória Adaptativa para a Etnobiologia Evolutiva

Um fato interessante que deriva da ideia da memória adaptativa diz respeito ao entendimento de como o viés de memória pode afetar a relação das pessoas com a natureza (SILVA et al., 2017). A memória adaptativa nos fornece alguns insights importantes que podem ajudar as etnobiólogas e os etnobiólogos evolutivos a entender como a cognição humana funciona em face dos desafios ambientais. Um etnobiólogo ou etnobióloga pode questionar, por exemplo, por que as pessoas se lembram de um recurso alimentar melhor do que de outro? Por que as pessoas se lembram de uma determinada planta medicinal melhor do que de outra? Como lembrar de informações que são importantes para a sobrevivência afeta a relação do ser humano com a biota? Essas são apenas algumas das perguntas que podem ser feitas usando a memória adaptativa como cenário teórico. A seguir, detalhamos alguns insights teóricos que consideramos importantes e que podem servir de base para o desenvolvimento de estudos em etnobiologia evolutiva.

A memória adaptativa é observada em diferentes contextos ambientais e culturais

A adaptação da memória para privilegiar informações importantes sobre a sobrevivência é inata na espécie humana (NAIRNE et al., 2007), e as adversidades dos ambientes ancestrais não estão necessariamente ligadas a memória (YOUNG et al., 2012; YANG et al., 2014). Essa característica mnemônica pode ser observada em diferentes contextos ambientais e culturais (ver BARRETT; BROESCH 2012; BARRETT et al., 2016; SOUSA et al., 2016).

A memória adaptativa funciona hierarquicamente

A memória humana favorece algumas informações que são relevantes para a sobrevivência melhor do que outras (ver SANDRY et al., 2013; SILVA et al., 2019). Além disso, há uma tendência da memória de priorizar informações relacionadas aos desafios dos ambientes naturais em detrimento de outras informações que também são importantes para a sobrevivência (ver BARRETT et al., 2016).

Os humanos têm uma mente naturalista universal

Uma maior retenção na memória humana de informações relevantes para a sobrevivência ocorre quando está associada a ambientes naturais (ver exemplo em BARRETT et al., 2016). Isso nos leva a considerar a existência de uma mente humana naturalista universal (ALBUQUERQUE; FERREIRA JÚNIOR, 2017). A mente naturalista pode ser entendida como uma estrutura de cognição que evoluiu em resposta às adversidades de diferentes ambientes naturais ocupados pelos hominídeos ao longo do processo evolutivo (ALBUQUERQUE; FERREIRA JÚNIOR, 2017). As pressões desses diferentes ambientes podem ter levado o cérebro humano a desenvolver um aparato cognitivo e comportamental eficaz para solucionar os desafios naturais mais recorrentes, ou seja, que apresentam maior regularidade no ambiente (FERREIRA JÚNIOR et al., 2019).

Essa suposição pode ser a chave para entender por que certas informações relacionadas ao mundo natural são mais lembradas pelos humanos.

Assim, concordamos com a ideia proposta por Barrett (2012) de que nossos mecanismos mentais podem ser heterogêneos, com novas estruturas evoluindo a partir de estruturas mais antigas, em uma combinação de características ancestrais com características relativamente recentes. Nesse caso, as adaptações cognitivas observadas em humanos modernos não seriam necessariamente produtos de respostas a adversidades impostas por um ambiente específico do passado ancestral, mas podem refletir a seleção de estratégias gerais da mente humana para enfrentar desafios em diversos ambientes.

Em resumo, acreditamos que: i) as pessoas se lembram de informações importantes para a sobrevivência independentemente de seu ambiente e cultura; ii) a capacidade de lembrar essas informações não está exclusivamente ligada às prioridades ancestrais; iii) a informação adaptativa é lembrada hierarquicamente; e iv) somos dotados de uma mente naturalista capaz de processar informações sobre o mundo natural. Ao assumir que essas suposições são verdadeiras, podemos investigar em estudos de EE, por exemplo: que tipos de mecanismos cognitivos podem estar envolvidos na intensificação de informações que são relevantes para a sobrevivência em ambientes modernos; quais informações sobre o mundo natural são priorizadas na memória; quais fatores intensificam a recordação; e como isso pode influenciar o comportamento humano em relação à natureza.

Frequência de envolvimento e experiência anterior com eventos de risco agem como potencializadores da memória adaptativa em sistemas socioecológicos

Alguns estudos empíricos apontaram que variáveis ambientais, como a frequência de envolvimento em um evento de risco e história de vida, como experiências pessoais anteriores com um evento crítico, podem intensificar a lembrança de informações importantes sobre a sobrevivência na memória humana (ver RUIN et al., 2007; SACHS et al., 2017; SCHEIDELER et al., 2017). Além disso, no contexto etnobiológico, existem evidências que apontam para uma possível influência destas variáveis na recordação deste tipo de informação em sistemas socioecológicos (ver SOUSA et al., 2016). Isso sugere a existência de uma possível influência da frequência com que os eventos ambientais afetam as pessoas e a experiência anterior com eles como intensificadores dessa informação adaptativa na memória humana em sistemas socioecológicos. Portanto, acreditamos que as mesmas variáveis que levam à priorização na memória de informações para lidar com uma situação de risco — frequência e experiência anterior — também podem ser os mecanismos responsáveis por interferir nas estratégias humanas para lidar com as adversidades de seu ambiente. Santoro e colaboradores (2015) notaram, por exemplo, que as pessoas tendem a selecionar mais espécies de plantas para o tratamento de doenças recorrentes nos sistemas médicos locais. Em outro estudo, Santoro e colaboradores (2017) também observaram que a incidência da malária afetou o uso de plantas medicinais antimaláricas em grupos humanos africanos em períodos em que não havia políticas públicas de controle da doença. Portanto, esse aspecto pode ser indicativo de que a frequência de envolvimento com um evento de risco pode intensificar a evocação de informações na memória humana. Isso pode desencadear maiores esforços para resolvê-lo, levando a modificações substanciais nos nichos ambientais que as pessoas ocupam.

Além disso, acreditamos que as mudanças geradas nos nichos ambientais em que as pessoas vivem podem ter se originado desses mesmos vieses cognitivos e que também podem afetar a lembrança de informações importantes para a sobrevivência. De acordo com Silva e colaboradores (2017), por exemplo, a seleção de um determinado recurso medicinal por meio de suas vantagens atreladas ao uso dentro de um sistema médico local pode levar a vieses cognitivos que tornam as informações sobre esse recurso mais memoráveis. Assim, um exemplo hipotético para tal suposição seria que as pessoas, ao lidarem com doenças recorrentes, também tenderiam a concentrar os recursos necessários para tratá-las próximos as suas residências — vantagens de otimização dentro do sistema médico —, o que poderia levar, neste caso, a estes recursos se tornarem mais memoráveis devido a influência do contato contínuo e direto com o mesmo.

Essa discussão, combinada com as evidências da memória hierárquica, pode sugerir que a mente naturalista lida com a complexidade ambiental filtrando as informações sobre a sobrevivência, priorizando aquelas que afetam as pessoas imediatamente, em detrimento de outras informações que envolvem situações menos imediatas. Isso pode explicar tanto as evidências de estudos etnobiológicos envolvendo doenças recorrentes, quanto o comportamento observado na memória hierárquica. Por exemplo, o fato de que informações sobre animais perigosos são mais lembradas do que alimentos perigosos (BARRETT et al., 2016) pode revelar o funcionamento de uma mente que opera para lidar com situações atuais. No passado evolutivo, identificar e fugir de um predador pode ter exigido uma maior ativação de áreas do cérebro ligadas à memória para responder imediatamente a esta situação quando comparada à identificação de alimentos tóxicos (uma situação que também afeta a sobrevivência, mas menos imediatamente). Este pode ter sido o cenário evolutivo da mente naturalista, de modo que hoje se reflete na construção de sistemas socioecológicos, direcionados para responder a eventos recorrentes.

Assim, compreender quais tipos de variáveis interferem na lembrança de informações adaptativas que envolvem o mundo natural pode ser o primeiro passo para entender como a mente naturalista humana evoluiu e opera ao lidar com as adversidades da natureza, bem como os padrões de comportamento humano que podem emergir dessa relação. A compreensão desses mecanismos pode representar um passo importante na compreensão do comportamento humano em relação aos recursos biológicos, que é o foco de interesse da etnobiologia evolutiva.

Considerações Finais

Traçar o caminho evolutivo do ser humano não é uma tarefa fácil, talvez seja por isso que tantas disciplinas científicas conversem entre si, e promover esse diálogo é uma das missões-chave da EE (ver ALBUQUERQUE; FERREIRA JÚNIOR, 2017). Este é um empreendimento recente, que requer a construção de pontes. Para Stanford (2019), superar as barreiras entre a psicologia e as ciências sociais e entre essas ciências e aquelas que estudam outros organismos são etapas fundamentais.

Nesse sentido, é difícil afirmar, por exemplo, que as atitudes das pessoas em relação à natureza resultam apenas de fatores genéticos ou culturais. Nossa capacidade cognitiva avançada parece ter evoluído não apenas por meio de fatores genéticos, mas também por meio de práticas humanas, indicando uma coevolução entre genes e cultura (ALTMAN; MESOUDI, 2019; STANFORD, 2019; ver também ALBUQUERQUE et al., 2019).

Considerando que certas capacidades mentais devem estar presentes para que uma determinada cultura ou sistema socioecológico evolua (ver STANFORD 2019), os estudos etnobiológicos que analisam os padrões de comportamento humano sem levar em consideração os fatores evolutivos que precedem um determinado comportamento podem não capturar completamente este fenômeno. Assim, acreditamos que o diálogo entre as disciplinas científicas que analisam a relação entre as pessoas e seu ambiente é relevante para o crescimento da EE.

CAPÍTULO 2

MEMORY FOR MEDICINAL PLANTS REMAINS IN ANCIENT AND MODERN ENVIRONMENTS SUGGESTING AN EVOLVED ADAPTEDNESS

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Memory for medicinal plants remains in ancient and modern environments suggesting an evolved adaptedness

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Abstract

Adaptive memory is the propensity of human memory to easily store and retrieve important information to deal with challenges related to the Pleistocene. Recent evidence shows that humans have had a multiregional evolution across the African continent, including the rainforests and deciduous forests; however, there is little evidence regarding the implications of these origins and the relevant and recurring challenges of these environments on survival processing advantage in memory. In this study, we conducted an experiment with volunteers to analyze whether adaptive memory operates in the retrieval of important information to solve challenges of using medicinal plants to treat diseases in the ancestral environments of the savanna, rainforests, and deciduous forests compared to the modern environments of desert, tundra, coniferous forest, and urban areas. We used simulated survival environments and asked volunteers (30 per simulated scenario) to imagine themselves sick in one of these environments and needing to find medicinal plants to treat their disease. The volunteers rated the relevance of 32 words to solve this challenge, followed by a surprise memory test. Our results showed no

ancestral priority in recalling relevant information, as both ancestral and modern environments showed a similar recall of relevant information. This suggests that the evolved cognitive apparatus allows human beings to survive and can create survival strategies to face challenges imposed in various environments. We believe that this is only possible if the human mind operates through a flexible cognitive mechanism. This flexibility can reflect, for example, the different environments that the first hominids inhabited and the different dangerous situations that they faced.

Keywords Human evolution, Survival processing, Evolved psychological mechanisms, Evolutionary Psychology, Evolutionary Ethnobiology.

Introduction

Adaptive memory refers to cognitive adaptation based on survival that prioritizes the storage and retrieval of important information in human memory to deal with recurring challenges related to the Pleistocene, 2,5 millions of years ago — that is, ancestral priority in the functioning of memory [1]. This may reflect the importance of ancestral environments in the evolution of most human psychological mechanisms (see [2]), enabling better mnemonic performance to occur when induced by problems present in ancestral settings, such as escaping predators and treating infections (see [3,4]). This adaptive memory bias leads to greater information retention, regardless of the specific proximate mechanisms that may be involved [1]. In this sense, a mnemonic adaptation refers to the selective pressures that shaped a memory that helped early human beings to solve adaptive problems and, therefore, increased the chances of survival and reproduction [5].

For example, it was observed that situations involving the search for medicinal plants for treating an infection in a savanna ancestral environment promoted survival advantage in memory processing compared to the modern environment [3]. Other studies analyzing this mnemonic adaptation also obtained similar results (see [5-10]), including studies among people living in different environmental contexts (11, 12). In this sense, the book published by Schwartz et al. [13] gathers several theoretical and empirical works about the adaptive nature of memory. In addition, remembering the location of food, the habitat of a predator or a partner available to mate facilitated the survival and reproductive success of hominids [3,14,15].

These mental adaptations were shaped by the way hunter-gatherer hominids solved recurrent adaptive problems in ancestral environments [2]. However, recent evidence shows that human beings have undergone a multiregional evolution across the African continent and in other regions of the planet [16-20], with little evidence on the implications of these origins on adaptive memory (see [15,21]). For instance, a study by Yang et al. [15], showed that important information for survival is remembered by people both in ancestral survival scenarios (savanna-like pastures) and in non-ancestral/modern environments (mountains). Moreover, a study by Silva et al. [22] provided evidence that the previous experience of people with common illnesses and the frequency of these illnesses intensifies the memorization and retrieval of important information to deal with these illnesses. This suggests that the human mind can adaptively respond well to recurrent threats in the current environment. Therefore, it is reasonable to consider that adaptive memory can operate in recent environments and in other evolutionary environments besides the savanna, such as in humid and dense tropical environments; however, this has not been tested so far.

During evolutionary history, the first human beings had to constantly interact with the environment, using natural resources to obtain nutrients or avoiding dangers and threats from predators. This indicates that their interactions may have affected our cognitive apparatus such that the human mind has adapted and developed psychological mechanisms responding to a wide range of challenging situations [2]. Recurrent selection pressures in the *environment of evolutionary adaptedness*, acting over evolutionary time on a regular basis, boosted the construction of mental adaptations in the first humans to solve lasting adaptive problems [2]. Environment of evolutionary adaptedness does not refer to a specific environment or time; it is a set of statistical factors of recurrent selection pressures or cause and effect relationships that drove the increase in the frequency of certain alleles underlying an adaptation, until they became typical species or promoted a frequency-dependent balance [2]. According to Tooby and Cosmides [2], evolutionary processes are slow and require thousands of years to develop complex cognitive adaptations; therefore, the human mind remains adapted to the Pleistocene savanna. However, this concept does not consider two important aspects of the evolutionary history of *Homo sapiens*: i) human evolution and development may have occurred in various environments during the Pleistocene [18, 20]; and ii) human activities can accelerate biological evolution, thus modifying genetically inherited predispositions (see [23]). These aspects may even reflect flexible mental adaptations, which integrate the mechanisms molded in paleoenvironments with mechanisms built during the individual's ontogenetic development [24]. For example, an idea proposed by Orians [25] assume that exist the predisposition of

human beings to prefer savanna environments, due to the importance of this environment during evolutionary history, which, being an environment with sparse trees that allowed a panoramic view, facilitated, among other things, the observation of the approach of predators, which helped in the survival and reproduction of hominids. However, this preference is not observed in some cultures, which may result from the establishment of human beings in different modern environments [26, 27]. In addition, the study by Soderstrom and McCabe [4] brought evidence that the good performance of recall occurs in modern (city) and ancestral (pasture) scenarios, suggesting that in some situations there is no ancestral priority in the survival processing advantage in memory.

In this sense, based on recent paleoanthropological evidence from the fossils of the first human beings [18,20,28,29], we consider the rainforest, deciduous forests, and the savanna as ancestral environments. For example, recent fossil evidence suggests that *H. sapiens* may have originated and evolved in distinct regions throughout the African continent (see [17,19,30]). The first hominids adapted to various environments during the Pleistocene over a wide latitudinal range, such as the temperate north (which includes deciduous forests) the subtropical region of China, and in the tropical regions of Southeast Asia [18,20,29]. At the end of the Pleistocene, some *H. sapiens* had already occupied the cold temperate environments of the Arctic region [31]. Richerson and Boyd [31] even argue that the long and slow evolutionary history of human beings in different environments may have driven the growth and development of the brain as we know it today, because the human construction of subsistence systems adapted to spatial variation.

In this study, we analyzed the performance of human memory in situations of survival in the ancestral savanna, rainforest, and deciduous forest environments, and in the modern coniferous forest, desert, tundra, and urban environments, to investigate whether an ancestral priority of adaptive memory really exists. The modern environments considered here are regions in which there has been no paleoanthropological evidence about hominid origin and evolution until now. This study can help to elucidate the controversial results in literature that may reflect the conception of evolutionary psychology suggesting that we evolved in a specific environment (savanna) and that is why we adaptively respond better to challenges related to this biome, not considering, for example, the ancestral environment of the rainforest.

For this, we carried out an experiment adapted from Nairne et al. [1] in which we simulated both ancestral and modern survival scenarios. In the typical survival processing paradigm, participants imagined that they were trapped in a savanna without any survival materials and must face potential dangers, and that they needed to evaluate a list of words and

their relevance to survive in the relevant scenario [32]. In this study, we asked volunteers to assess the relevance of information to solve the recurring challenges imposed in these scenarios and later subjected them to a surprise memory test. The memory test allowed us to analyze whether the relevant information was remembered when related to ancestral environments.

If human evolution was in fact multiregional, it is reasonable to consider that adaptive memory is a reflection of an evolutionary history that has trodden several paths, with hominids venturing and adapting to threats that exist in hot, dry, and sparse environments as well as in humid and dense environments. Therefore, these evolutionary paths must have some effect on adaptive memory. We suggest that the understanding of how adaptive memory operates can be more complete with the expansion of its analysis in a manner that encompasses rainforests as well as modern environments.

Thus, we tested the hypothesis that there is an ancestral priority in the cognitive strategies mobilized in the human mind to find medicinal plants to treat diseases. The challenge related to the search for medicinal plants for treating diseases is an interesting model for a broader understanding of adaptive memory, as this was a basic recurrent challenge essential for the survival and evolution of hominids in ancestral environments [3,20,33-35]. In our experiment, we predicted that, on average, people would significantly remember the words classified as most relevant to finding and using medicinal plants in the simulated ancestral survival scenarios (savanna, rainforest, and deciduous forest) when compared to the modern scenarios.

There is evidence that *Homo sapiens* and *H. neanderthalensis* have used several parts of different plants for medicinal and technological purposes [36,37]. Situations of parasite infections or invasion by predators during foraging activities may have stimulated the first humans to look for medicinal plants [38]. In addition, *Homo habilis* used medicinal plants to treat diseases based on observation of plant-based self-medication by other animals [39]. The use of medicinal plants by non-human primates may also involve different plant parts. For instance, some orangutans (*Pongo pygmaeus*) in Indonesia ingest *Dracaena cantleyi* leaves for the treatment of parasites [40]. Although the therapeutic use of plants is understood to be essential for the survival and evolution of hominids, the events that led to this behavior are still uncertain, with only few hypotheses about its origin (for a complete argument see Albuquerque et al. [33]).

In this sense, we conducted an empirical experiment that analyzed how human memory stores and retrieves the relevant information to challenges related to the use of medicinal plants in different environments. We used the same challenge related to medicinal plants in all

simulated environments because using qualitatively different survival threats (for example, escape from a predator in the savannah *versus* escape from a murderer in the city) could lead to different levels of threat meaning [41], that is, one threat can be perceived as more dangerous than the other. Therefore, our aim was to obtain evidence about how human memory may have evolved to be versatile in solving the problems imposed by ancestral and recent environments.

Materials and methods

Experiment and word selection

We designed an experiment, adapted from the work of Nairne et al. [1], analyzing the survival processing paradigm, in which we simulated different survival scenarios wherein each volunteer evaluated the relevance of information to perform the task of finding and using medicinal plants to treat a disease. We do not use a control scenario in our experiment. Although, we chose to only use scenarios related to a survival situation, considering that the task of looking for medicinal plants to treat diseases activates the advantage of survival processing in memory (see [3]). The scenarios encompassed ancestral environments — rainforests, deciduous forests, and savanna — and modern environments — coniferous forests, deserts, tundra, and urban. We maintained the same survival conditions in all environments. The objective was to analyze whether the most relevant information would be quantitatively more recalled in a free recall surprise test. We predicted that relevant information would be best remembered when the challenge was present in ancestral environments.

The "information" in our experiment is represented by words (concrete nouns) that act as stimuli in the tests of memorization (see [1]). The relevance of this information was decided by the volunteers themselves, as even seemingly irrelevant stimuli for fitness, such as a pencil, could become relevant depending on the situation and a jacket could be relevant depending on the location [42]. Relevance was measured using a Likert scale that ranged from 5 for extremely relevant to 1 for extremely irrelevant. In the recall test, our objective was not to analyze the word itself, but rather if the relevance given to each word would influence its recall depending on the environment, regardless of the meaning of the information.

Thus, we randomly selected 32 words that were unrelated concrete nouns, based on the free association norms for Brazilian Portuguese words in memory studies, which include 1004 standardized words [43]. The selection criterion was based on two aspects: i) concrete nouns, as they generate less confusion in free recall tests; and ii) unrelated nouns that have little or no semantic relationship, as this relationship can be a confusing factor in the analysis. The 32

selected words that we used as a stimulus, followed by their translation into English, are described in S1 Appendix. The same set of 32 words was used for all simulated survival scenarios. The words were randomized before being presented to each participant.

Survival scenarios

To test whether there is an ancestral priority in the cognitive strategies mobilized in the human mind, we use simulated survival scenarios that are dangerous situations (see [1,33]), but made some adaptations. In adaptive memory studies, survival scenarios usually cover only the ancestral savanna environment and the modern city and mountains, among others. However, to test our hypothesis, we used the other five great terrestrial biomes, considering the rainforest and deciduous forest as ancestral environments, according to the classification by Odum [44], to represent the scenarios of survival, maintaining the same situation of danger in all the scenarios. In addition, we displayed an image of the landscape corresponding to the respective environment to each participant so that the situation had another associated stimulus. The use of images is common in psychology studies that analyze, for example, the preference for landscapes by human beings, as carefully selected images promote a good representation of the actual environment (see [27]). In this study, we used seven images used by Moura et al. [27]. We describe all seven simulated scenarios used in S2 Appendix. Below is an example of one of the simulated scenarios used in the experiment:

Scenario: *"Imagine that you are alone and sick in a rainforest, without basic materials for survival. In the coming days, you will need to find and use medicinal plants to treat this disease. We will show you a list of words, and would like you to assess the relevance of each of these words in your attempt to treat the disease and to survive in this environment".*

Participants

We recruited 210 volunteers (age mean = 22.4 years; *SD* = 4.07), all students from the Universidade Federal Rural de Pernambuco, Brazil, including 51% women and 49% men, with the objective of analyzing how adaptive memory operates in different simulated survival environments with challenges related to the use of medicinal plants. Volunteers were recruited through direct contact with each volunteer. Before the experiment, the following question was asked: "*Do you know what medicinal plants are*?", with answer options as "yes" or "no". Volunteers who did not know what medicinal plants were were excluded from the study, as not

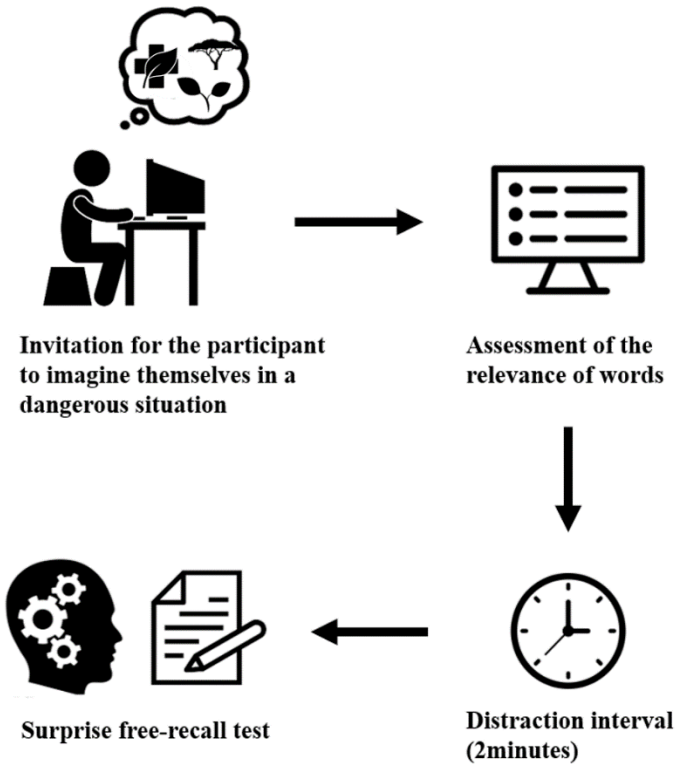
knowing the model used as a challenge (medicinal plants) could bias the experiment. New recruitments were made to replace these participants.

The Research Ethics Committee involving human beings at the Universidade de Pernambuco approved this study (decision number 2.944.271). All participants read and signed the Free and Informed Consent Form, which explained the procedures and objectives of the research.

Procedure

Participants were tested individually in an isolated room without any external interruption. The volunteers were divided into seven groups (n = 30 in each group) that differed by the type of simulated environment. These environments were considered ancestral — rainforest, deciduous forest, and savanna — and modern — coniferous forest, desert, tundra, and urban. The objective was to observe how information processing in memory varies depending on the type of environment. In the first part of the experiment (Fig 1), a simulated survival scenario was presented to the participants, and each participant was instructed to assess the relevance of 32 words to survive in the presented danger situation. Each word was exposed on a computer screen for 5 seconds. Immediately after that, there was a 2-minute distraction interval, which is the time necessary to avoid the tendency to remember the first elements of a list (primacy effect) and the last elements (recency effect), during which the participants filled out a form about demographics. After that, a surprise test of free recall was made, in which the participants were instructed to write the maximum number of evaluated words that they could remember on a sheet of paper, regardless of the order, within 10 minutes. Each experiment had a total duration of 30 minutes. We expected that the most relevant words were retrieved in the memory test when related to the ancestral environment.

Fig 1. Scheme of the experiment used to analyze the functioning of adaptive memory in simulated situations of danger in ancient and modern environments.



Data analysis

To test our hypothesis that there is an ancestral priority in the cognitive strategies mobilized in the human mind to find medicinal plants to treat diseases, we developed mixed generalized linear models (GLMs) with binomial distribution, using the *R lme4* package [45]. As the environment and relevance of the information are factors that influence memory in the recall test, the dependent variable was the *recall* of the words evaluated by the participants. Therefore, the independent variables were the types of simulated *environments*, the words' *relevance*, and the *interaction* between these variables. As each participant has a different memorization capacity, we included the participants as a random factor to discard the effect of the difference in memorization among the three models developed. The effect size of the variables was measured using the R broom.mixed package [46]. All analyses were performed in the R version 3.6.1 environment [47].

We adjusted the model to obtain the lowest AIC value, as proposed by Agresti [48]. Although the variable relevance when isolated, was not significant (assuming a significance

level of $p < 0.001$), we included it in the adjusted model (AIC = 9013.2), as analysis of the more complex model showed significant interactions between the variables (relevance + environment) that influenced the recall. For Agresti [48], when the variables interact significantly, the variables that make up this interaction should not be removed from the model. The resulting model explains about 4.5% of the variation observed in the recall (R2 marginal = 0.044). We also created a graph to observe the relationship between the variables using the ggplot2 package [49].

Results

The relevance of the words influenced their recall by the participants (n = 210, which was 30 per scenario) in the modern urban, tundra, and desert environments, in addition to the ancestral environments of the savanna and rainforests ($p < 0.001$). The analysis of our most complex model, which had a better fit (AIC = 9013.2), showed that the interactions between the relevance and environment variables had a significant effect on the model.

We observed that the following interactions were significant: relevance + desert (z = 3.893; p = 9.90e-05), relevance + savanna (z = 3.008; p = 0.00263); relevance + rainforest (z = 4.694; p = 2.67e-06); relevance + tundra (z = 5.042; p = 4.61e-07); relevance + urban (z = 4.447; p = 8.72e-06) (Table 1) (Fig 2). This means that the greater the relevance of information, which ranged from 1 to 5 on the Likert scale — to use medicinal plants to treat a disease in a given environment — in this case, the desert, savanna, rainforest, tundra, and urban environments — the more it is recovered in the memory test. However, the relevance + deciduous (z = 0.932; p = 0.35126) and relevance + coniferous (z = 0.784; p = 0.43313) interactions were not significant. The interactions show that for each unit of increased relevance, the chances of a word being remembered in the tundra environment are increased by approximately 35% (OR = 1.35), in the rainforest by 32% (OR = 1.32), in the urban environment by 30% (OR = 1.30), in the desert by 25% (OR = 1.25), and in the savanna by 19% (OR = 1.19) (Table 1). Each of the 32 words used in the experiment is presented in S1 Appendix, along with descriptive information on the average classification of each word and the recall ratio (95% confidence interval) when processed in each environment.

Fig 2. Relationship between the relevance + environment interaction and the recall of the participants. The colored lines represent the regression line of the relationship between the variables. The regression line inclines significantly in the desert, savanna, rainforest, tundra, and urban environments. The more relevant a word is, the more the person retrieves this information in the desert, rainforest, tundra, savanna, and urban environments.

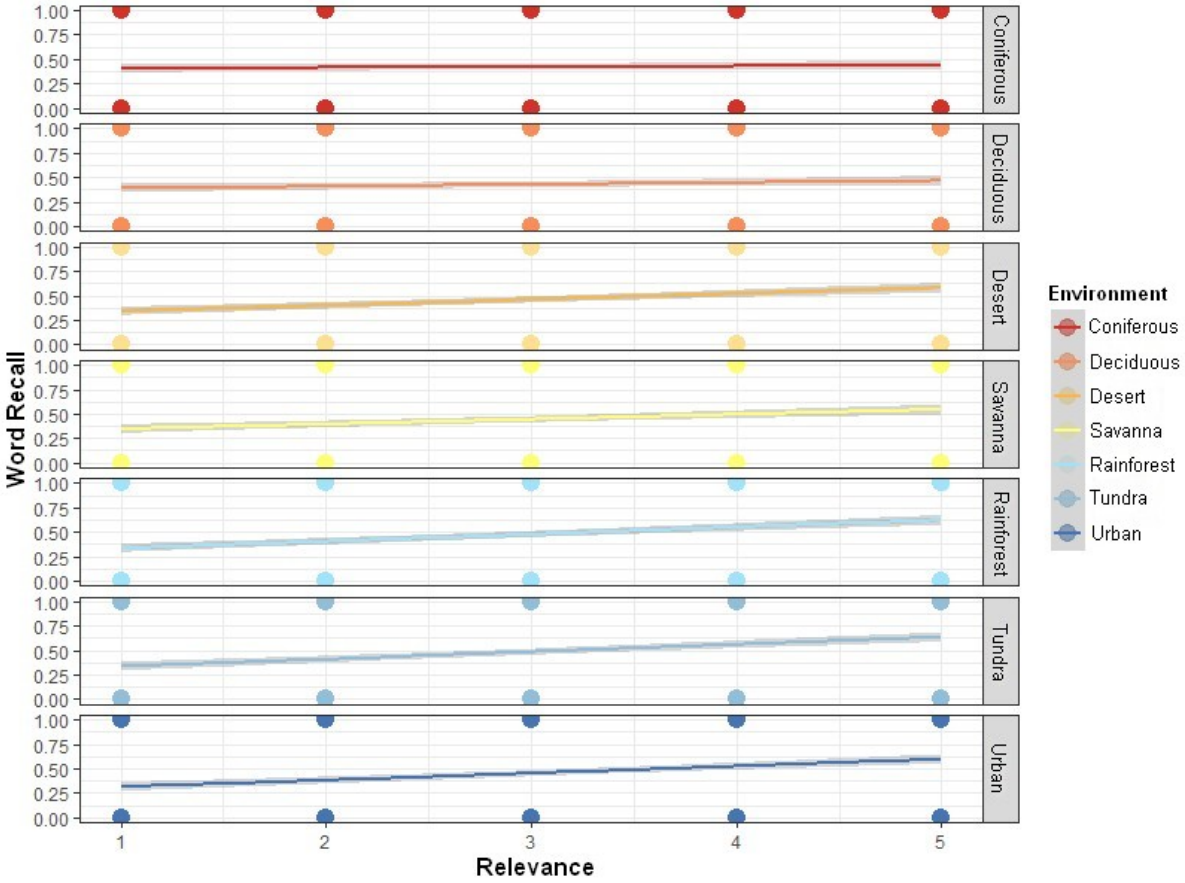


Table 1. Results of binomial GLM, estimated regression parameters, standard errors, z values, p values and effect size (in Odds ratio) estimated for relevance in each of the interactions (environments + relevance) that we used in the model, accompanied with the respective confidence intervals.

Interactions (relevance + environment)	Estimate	Std. Error	z value	Pr(>|z|)	Odds ratio	Low conf. (2.5%)	High conf. (97.5%)

(Intercept)	-0.41649	0.13872	-3.002	0.00268	0.659	0.502	0.865
Coniferous forest	0.03188	0.04068	0.784	0.43313	1.03	0.502	0.865
Deciduous forest	0.05292	0.05677	0.932	0.35126	1.05	0.943	1.18
Desert	0.22640	0.05816	3.893	9.90e-05	1.25	1.12	1.41
Savanna	0.17676	0.05876	3.008	0.00263	1.19	1.06	1.34
Rainforest	0.27559	0.05870	4.694	2.67e-06	1.32	1.17	1.48
Tundra	0.29955	0.05941	5.042	4.61e-07	1.35	1.20	1.52
Urban	0.26235	0.05900	4.447	8.72e-06	1.30	1.16	1.46

Comparison of word evaluations and the proportion of recall between environments

We performed an additional Kruskal–Wallis test (non-parametric test) to compare the word evaluation and the proportion of recall between all survival scenarios. This test was chosen because our data had a non-normal and heteroscedastic distribution.

The comparison of word evaluation values showed that there were no significant differences in the relevance given to the words in each environment ($H = 1.12$; $p = 0.98$). The descriptive analysis results of the words assessment are shown in Table 2.

Table 2. Median differences (Kruskal–Wallis) and the descriptive analysis of the words rating in the survivor scenarios.

H	***N***	**Survival scenarios**	**Median**	**Mean**	**Standard deviation**

1.12	30	Coniferous forest	2	2.76	1.63
		Deciduous forest	3	2.86	1.68
		Desert	3	2.79	1.63
		Savanna	3	2.78	1.58
		Rainforest	3	2.76	1.62
		Tundra	3	2.82	1.60
		Urban	3	2.99	1.59

Regarding comparison of the proportion of words remembered in each environment, there were also no significant differences ($H = 1.42$; $p = 0.96$). The descriptive analysis results of the proportion correct recall are shown in Table 3 (Table 3). Thus, both the evaluation and the proportion of word recall were similar between the environments. However, as noted in the GLMM analysis, the greater the relevance of information in the tundra, rainforest, urban, desert, and savanna environments, the more are its chances of recovery.

Table 3. Median differences (Kruskal–Wallis) and the descriptive analysis of the proportion correct recall in the survivor scenarios.

H	***N***	**Survival scenarios**	**Recall**	**Median**	**Mean**	**Standard deviation**
1.42	30	Coniferous forest	0.42	12	12.59	5.09
	30	Deciduous forest	0.41	12.5	12.75	5.31
	30	Desert	0.43	11.5	13.46	6.84
	30	Savanna	0.45	13	13.06	6.32
	30	Rainforest	0.47	14.5	13.87	7.09
	30	Tundra	0.47	11	14.18	7.34
	30	Urban	0.45	13.5	13.62	6.80

Discussion

This study comprised an analysis of the functioning of adaptive memory in different simulated environments rejected the hypothesis that there is only ancestral priority in the way it operates, i.e., it is not restricted only to the savanna, rainforests, and deciduous forests. We provided evidence that relevant information to search for medicinal plants in the desert, rainforest, and tundra environments was also recovered in memory. Based on our evidence, human cognition may have been selected slowly over evolutionary history in response to recurring challenges, present in diverse environments explored by hominids, such as the use of medicinal plants to treat diseases. According to Nairne and Pandeirada [50], the effects of survival processing on memory may be acting through a general survival optimization system that deals with varied challenges, selected for having helped human beings to face recurrent threats both in ancestral as well as modern environments. For example, the effects of survival processing were observed in different simulated scenarios, such as "city" and even in "outer space" [21] and in situations involving zombie threats [51].

In this sense, the human mind adaptations exist because they helped to solve recurrent and relevant adaptive problems to survival or reproduction of the hominids during evolutionary history (see [2]). Since in our study in the deciduous forest and coniferous forest environments there was no significant interaction with the relevance of the information, this may reflect the absence or less occurrence of certain challenges in some environments where human populations have settled over time. However, this needs to be analyzed in future studies.

In fact, the environments explored by hominids are not restricted to the savanna of the African continent and may include other biomes (see [18,20,31]). For example, there is evidence that the oldest hominid, *Graecopithecus freybergi*, inhabited a savanna environment in the region of Greece, between 7.37 and 7.11 million years (Ma) [16]. In addition, according to Zhu et al. [29], fossil evidence indicates that hominids dispersed from the African continent towards East Asia at least 2.1 Ma. This suggests that even at the beginning of the Pleistocene, hominids entered Asia, adapting to different geographic and climatic configurations [52].

For a long time, there was a consensus that *H. sapiens* originated in South Africa, but fossil evidence involving recent discoveries in the Gruta da Aroeira in Portugal [53], added to the evidence that *H. sapiens* inhabiting the Morocco region had a mixture of *H. sapiens* fossil characteristics from other parts of Africa, suggest a multicentric genesis for our species [17,19]. Therefore, this evidence suggests that several regions may have been important during the evolution of humans.

Although the savanna is still considered the main environment of human evolution, fossil evidence indicates that the origin and large divisions of hominids may have occurred outside Africa (see [16,30,54]). There is even evidence of hominid adaptations in humid and dense environments. Among these adaptations, we can include the use of fire [28], and traces of foraging activities in the interior of the rainforest [55]. The idea of hominid origin and evolution in rainforests is not new. Andrews [56] had already proposed the possibility of the first hominids to have evolved in both closed and open forests. This proposition has gained strength as new paleoanthropological evidence of human evolution in the rainforests has emerged (see [18,20]).

In this sense, given that cognitive mechanisms result from responses to relevant and recurring selective pressures from ancestral environments, a challenge for evolutionary psychologists would be to expand their analysis in a way that covers the adaptive problems of different environments in which we evolve and the influence of the evolved psychological mechanisms in solving problems different from those found only in the African savanna [57]. For example, dealing with infections was a challenge in several environments during the Pleistocene, and success in this, regardless of the environment in which such an adaptive problem was present, may have been crucial for the survival and reproduction of hominids [33]. This would help explain, for example, why Yang et al. [15] found that important information for survival is recovered both in ancient survival scenarios as well as in modern environments. The work by Silva et al. [22] also showed that the challenges encountered in current environments are important for our cognition.

We do not deny the important role of the ancestral past in the construction of the human mind, but it is essential to abandon the idea that we are still mentally predisposed to the ancestral environments of the Pleistocene. We provide evidence that human respond adaptively to challenges related to the use of medicinal plants present in ancient as well as modern scenarios. In this case, we assume that human beings have inherited adaptations from their hominid ancestors; however, human activities carried out in different environments over time can accelerate biological evolution and may modify genetically inherited predispositions (see [23,27,58]). Barrett [24] argues that certain adaptations can provide plasticity to the human mind. According to the author, it is possible that the human mind integrates both general and specific mechanisms, which were shaped during evolutionary history and by the individual's ontogenetic development. As per Barrett [24], the cognitive processes of human beings can operate through mechanisms of heterogeneous origin, with new structures evolving from older structures and ancestral characteristics combined with relatively recent characteristics. This

aspect of human cognition may have been important in reducing the incompatibility between ancestral and modern environments.

According to Tooby and Cosmides [2], evolutionary processes are slow and require several generations to develop complex psychological mechanisms. This argument supports the idea that we still act in the face of imposed environmental problems in a similar manner to our hominid ancestors during the Pleistocene (see [59]). A classic example is the preference for fatty and sweet foods, which is behavior adapted to ancestral environments with little fat availability, but poorly adapted in the current environment, thus increasing the incidence of cardiovascular illness [59]. However, there is recent robust evidence of significant genetic changes in human populations [58,60,61]. Although previous examples do not involve changes in cognitive aspects, it is probable that psychological mechanisms evolved in the Pleistocene may be subject to evolutionary processes that promote rapid changes in a few generations, being able to generate new cognitive structures that used "model" older mechanisms to adapt to today's environments challenges (see [24]). In this sense, evidence that people remember important information in modern environments, may indicate that there is no incompatibility, and that genetically inherited psychological mechanisms can be modified and adjusted to the current environment as well.

Our study provides evidence that adaptive memory can operate through a flexible and adaptive cognitive mechanism, as argued by some other scientists as well [14,15, 22,24,62-64]. However, the absence of a control scenario in our study limits the scope of the results, making it important to analyze the mnemonic performance in other survival scenarios compared to a control scenario. From an evolutionary point of view, memorizing information related to a wide range of environments and recurring danger situations over the generations may have given the first hominids greater ability to survive.

If this is true, cognitive adaptations do not just respond to situations related to a specific environment. The first hominids may have evolved psychological mechanisms, reusing pre-existing mechanisms, which adjusted to different environments during their evolution, not just being restricted to the Pleistocene era [31,24]. Thus, future studies should investigate the factors leading to certain environments and not just ancestral environments, to intensify the effect of survival processing advantage on memory and to determine the cognitive mechanisms that act as stimuli for information prioritization in memory.

Conclusion

The cognitive apparatus selected throughout evolution allows humans to survive and create survival strategies to face recurring challenges in various environments. Retrieving important information for survival related to the use of medicinal plants can be one of these strategies. We suggest that this is only possible if the human mind operates through an evolved versatility that gives it flexibility. This flexibility can reflect, for example, the different environments that the first hominids inhabited and the different and recurring situations of danger that they had to face.

Limitations and future research

The main limitation of this study was that the performance of memory was not compared to a control condition (for example, "moving" scenario commonly used in studies that analyze the survival paradigm). Therefore, this makes it difficult to understand whether the mnemonic performance was really good or bad between environments. In this sense, the absence of control limits our results, which leads us to conclude that ancient and modern survival scenarios produce similar recall performance.

Furthermore, we analyzed the effect of survival processing advantage on the use of medicinal plants to treat diseases in people who do not have continuous contact with this type of challenge or a dependence on this natural resource. Recruiting participants who do not experience the challenges present in simulated survival scenarios in the real world is common in experimental psychology studies (see studies [3,8,9,63]). However, we argue this based on evidence that familiarity and previous experience with a recurring challenge in the environment influences how people perceive this risk [65,66]. It was also observed in an experiment that medicinal plants previously known by the participants were prioritized in memory and were more easily remembered [22].

Thus, we suggest that future studies use adjusted protocols to test adaptive memory in real systems, in which the population has already faced a challenging event at some point or that deals with the challenge presented by the researcher on a relatively daily basis. In addition, we suggest that future studies examine if prior knowledge about the use of medicinal plants to treat disease, or of another natural resource, is a critical factor in the performance of the survival processing advantage effect on memory.

Supporting information

S1 Appendix. Average word evaluations and the proportion of recall (95% confidence interval) in coniferous forest, deciduous forest, desert, savanna, rainforest, tundra, and urban environments.

		Coniferous		**Deciduous**		**Desert**		**Savanna**	
Words	Translated words (english)	Rating	Recall	Rating	Recall	Rating	Recall	Rating	Recall
água	water	5.00	0.26	5.00	0.43	4.70	0.83	3.96	0.86
agulha	needle	3.16	0.60	3.23	0.63	3.56	0.73	3.40	0.40
algodão	cotton	2.96	0.56	2.96	0.60	2.93	0.60	2.70	0.60
animal	animal	3.00	0.70	4.10	0.56	3.86	0.73	3.70	0.60
aranha	spider	2.50	0.30	1.56	0.26	1.80	0.30	1.66	0.20
bíblia	bible	1.66	0.43	1.90	0.40	1.80	0.40	1.93	0.60
cama	bed	2.56	0.36	2.66	0.40	2.90	0.53	2.60	0.63
camisa	shirt	4.16	0.40	4.23	0.43	3.73	0.53	3.46	0.46
carro	car	2.03	0.63	2.66	0.73	3.03	0.93	2.70	0.80
charuto	cigar	1.00	0.60	1.06	0.40	1.06	0.36	1.50	0.16
dinheiro	money	2.73	0.53	2.76	0.53	1.70	0.30	2.40	0.30
fogo	fire	4.06	0.30	4.26	0.30	4.16	0.40	3.70	0.63
gás	gas	3.03	0.33	3.33	0.26	2.96	0.23	2.13	0.53
geladeira	fridge	2.50	0.63	2.30	0.53	1.73	0.53	2.36	0.43
jaula	cage	1.26	0.16	1.50	0.16	1.80	0.16	2.00	0.23
lápis	pencil	1.96	0.36	2.03	0.30	1.80	0.26	1.73	0.36
maquina	machine	2.00	0.20	2.03	0.33	2.16	0.30	3.00	0.26
natureza	nature	4.80	0.70	4.73	0.63	4.70	0.60	4.43	0.63
paisagem	landscape	3.00	0.50	3.60	0.53	3.66	0.73	3.86	0.66
papel	paper	2.63	0.50	2.66	0.50	2.70	0.36	3.00	0.43
pessoas	people	4.16	0.60	4.30	0.33	4.30	0.73	4.56	0.53
prato	plate	1.53	0.40	1.46	0.56	1.73	0.33	1.40	0.80
refrigerante	soda	1.23	0.73	1.53	0.70	1.76	0.36	2.36	0.40
remédio	remedy	4.90	0.36	4.73	0.56	4.50	0.76	4.40	0.63
saco	bag	2.90	0.43	2.93	0.36	2.63	0.23	2.23	0.16

sangue	blood	3.80	0.26	4.20	0.30	4.06	0.53	4.10	0.73
tampa	lid	2.06	0.30	1.83	0.30	1.73	0.23	1.80	0.40
terra	soil	2.33	0.50	2.80	0.53	2.80	0.46	2.73	0.43
tumulo	tomb	1.26	0.16	1.10	0.10	1.36	0.10	1.63	0.10
violão	guitar	1.33	0.23	1.50	0.23	1.43	0.13	1.63	0.06
vitamina	vitamin	4.86	0.10	4.86	0.03	4.40	0.13	3.76	0.26
xícara	tea-cup	2.06	0.33	1.90	0.26	2.06	0.26	2.36	0.23
Averages		**2.76**	**0.42**	**2.86**	**0.41**	**2.79**	**0.43**	**2.78**	**0.45**

Materials S1 (continuation)

		Rainforest		**Tundra**		**Urban**	
Words	Translated words (english)	Rating	Recall	Rating	Recall	Rating	Recall
água	water	5.00	0.86	4.76	0.86	4.96	0.80
agulha	needle	3.10	0.70	3.43	0.76	3.40	0.70
algodão	cotton	3.13	0.56	3.36	0.66	3.56	0.56
animal	animal	3.93	0.76	3.80	0.73	3.80	0.73
aranha	spider	2.10	0.23	1.86	0.23	1.53	0.23
bíblia	bible	2.26	0.53	2.10	0.43	2.40	0.36
cama	bed	3.16	0.63	3.16	0.60	3.53	0.56
camisa	shirt	3.80	0.46	3.80	0.70	3.66	0.53
carro	car	1.93	0.80	2.73	0.90	3.23	0.90
charuto	cigar	1.06	0.20	1.20	0.30	1.20	0.23
dinheiro	money	1.50	0.50	2.43	0.36	4.23	0.36
fogo	fire	4.36	0.53	4.30	0.66	3.26	0.53
gás	gas	2.36	0.33	2.53	0.26	3.20	0.33
geladeira	fridge	1.43	0.60	2.20	0.60	2.83	0.50
jaula	cage	1.70	0.10	1.76	0.20	1.16	0.03
lápis	pencil	1.83	0.53	1.63	0.30	2.36	0.36
maquina	machine	1.83	0.40	2.16	0.26	2.06	0.26
natureza	nature	4.73	0.66	4.66	0.76	4.70	0.60
paisagem	landscape	3.73	0.63	3.46	0.80	3.36	0.56
papel	paper	2.43	0.36	2.70	0.33	2.73	0.43
pessoas	people	4.03	0.80	4.43	0.76	4.56	0.83
prato	plate	1.73	0.23	1.86	0.23	2.30	0.33
refrigerante	soda	1.30	0.26	1.46	0.33	1.33	0.50
remédio	remedy	4.73	0.80	4.63	0.83	4.83	0.73
saco	bag	3.00	0.26	2.66	0.33	3.06	0.13
sangue	blood	4.36	0.66	3.80	0.36	3.56	0.76
tampa	lid	1.76	0.13	1.56	0.26	2.00	0.36
terra	soil	3.06	0.36	2.90	0.50	3.33	0.46
tumulo	tomb	1.43	0.06	1.46	0.13	1.30	0.13
violão	guitar	1.30	0.20	1.56	0.20	1.50	0.26
vitamina	vitamin	4.53	0.16	3.96	0.20	4.63	0.13

xícara	tea-cup	1.80	0.90	2.00	0.23	2.30	0.26
Averages		**2.76**	**0.47**	**2.82**	**0.47**	**2.99**	**0.45**

S2 Appendix. Description of the simulated survival scenarios, texts of the situations, and the respective images of the environments.

Environment	**Text**	**Image**
Coniferous forest	*"Imagine that you are alone and sick in a coniferous forest, without basic materials for survival. In the coming days, you will need to find and use medicinal plants to treat this disease. We will show you a list of words, and we would like you to assess the relevance of each of these words in your attempt to treat the disease and survive in this environment".*	
Deciduous forest	*"Imagine that you are alone and sick in a deciduous forest, without basic materials for survival. In the coming days, you will need to find and use medicinal plants to treat this disease. We will show you a list of words, and we would like you to assess the relevance of each of these words in your attempt to treat the disease and survive in this environment".*	
Desert	*"Imagine that you are alone and sick in a desert, without basic materials for survival. In the coming days, you will need to find and use medicinal plants to treat this disease. We will show you a list of words, and we would like you to assess the relevance of each of these words in your attempt to treat the disease and survive in this environment".*	

Savanna	*"Imagine that you are alone and sick in a savanna, without basic materials for survival. In the coming days, you will need to find and use medicinal plants to treat this disease. We will show you a list of words, and we would like you to assess the relevance of each of these words in your attempt to treat the disease and survive in this environment".*	
Rainforest	*"Imagine that you are alone and sick in a rainforest, without basic materials for survival. In the coming days, you will need to find and use medicinal plants to treat this disease. We will show you a list of words, and we would like you to assess the relevance of each of these words in your attempt to treat the disease and survive in this environment".*	
Tundra	*"Imagine that you are alone and sick in a tundra, without basic materials for survival. In the coming days, you will need to find and use medicinal plants to treat this disease. We will show you a list of words, and we would like you to assess the relevance of each of these words in your attempt to treat the disease and survive in this environment".*	
Urban	*"Imagine that you are alone and sick in a city, without basic materials for survival. In the coming days, you will need to find and use medicinal plants to treat this disease. We will show you a list of words, and we would like you to assess the relevance of each of these words in your attempt to treat the disease and survive in this environment".*	

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CAPÍTULO 3

DOES THE CONGRUENCE OF INFORMATION-CONTEXT INFLUENCE THE ADAPTIVE MEMORY PERFORMANCE OF HUMAN BEINGS? AN ANALYSIS FROM THE USE OF MEDICINAL PLANTS

(Artigo submetido na revista Culture and Evolution – aguardando resposta)

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Does the Congruence of Information-Context Influence the Adaptive Memory Performance of Human Beings? An Analysis from the Use of Medicinal Plants

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Abstract

Psychological mechanisms evolved in the ancestral past as they helped the first hominids to survive and reproduce. A product of this evolution is the adaptive memory bias that can, among other things, facilitate the recall of information about medicinal plants. However, little is known about the immediate mechanisms that influence this mnemonic advantage. For example, information-context congruence can influence and promote memory retention advantages. In the present study, we analyzed the influence of congruence between the type of processing and the information to be remembered in a situation related to the use of medicinal plants. To do this, we simulated different survival scenarios, in which each volunteer assessed the relevance of information to perform the task of finding and using medicinal plants, and then remember these words in a surprise free recall test. To control the congruence of the information, we used three different word lists, with words relevant to the survival scenarios (survival list), words relevant to the robbery scenario (robbery list) and irrelevant words to both scenarios (Irrelevant list). Our results suggest that information-context congruence is an important factor that enhances mnemonic performance in ancestral and modern environments. Thus, human memory

can operate in a stimuli-sensitive and flexible way, generating adaptive responses according to the demands of the environment.

Keywords: Evolutionary Psychology, Evolutionary Ethnobiology, Evolved Psychological Mechanisms, Congruence Effect, Cognition.

1. Introduction

The recurrent challenges of the ancestral past may have generated a cognitive adaptation in memory that prioritizes the storage and retrieval of information important for survival (see Nairne, Thompson, & Pandeirada, 2007), and this mnemonic advantage was evidenced in several studies (see Weinstein, Bugg & Roediger, 2008; Bonin et al., 2019; Leding, 2019; Mieth et al., 2019; Silva et al., 2019). This memory adaptation was selected for having facilitated the survival and reproduction of hominids, as in situations that involved remembering and locating food, the habitat of a predator, partner available to mate (Nairne & Pandeirada, 2010; Sandry et al., 2013; Yang, Lau & Truong, 2014) or even to remember whether a person is a friend or an enemy (Schaper, Mieth & Bell, 2019). However, despite the strong evidence supporting the existence of the survival processing advantage, it is necessary to investigate how immediate mechanisms influence this mnemonic advantage (Nairne & Pandeirada, 2011). For example, the congruence of information can influence and promote memory retention advantages (Butler, Kang & Roediger, 2009).

The congruence effect is an important factor for the processing level paradigms (Butler et al., 2009), and refers to the improvement of memory performance when the encoding context — which are simulated situations involving a certain challenge — and the word to be remembered are compatible, forming the unit integrated word-context (Schulman, 1974). Thus, questions that produce the positive answer "yes" generate better target word retention than questions that produce the answer "no". For example, when someone is asked if the word "oxygen" fits into the phrase "*Do people breathe _____ to survive?*", that question promotes better retention of the word "oxygen" compared to questions that produce "no" answers as in the case of the question "*does the word 'electricity' fit in the same sentence about breathing to survive?*" (see Craik & Tulving, 1975). Therefore, the word "oxygen" in the first condition would be better remembered in a subsequent memory test. According to Schulman (1974), congruent coding produces better recall performance because memory can benefit from semantic cues more effectively to facilitate retrieval. The congruence effect on memory was observed in studies of different areas, and may even affect the mood of human beings (Ruci,

Tomes, & Zelenski, 2009; Christodoulou & Burke, 2016) and their social relationships (see Lee & Shen, 2009; Mudrik, Lamy & Deouell, 2010; Cassidy & Gutche ss, 2015; Lui et al., 2020).

According to Butler et al. (2009), some mnemonic advantages, such as that promoted by survival processing (Nairne et al., 2007), may actually reflect a congruence effect. Butler et al. (2009) analyzed the congruence effect in the survival processing paradigm, using a congruent word list for a robbery scenario, a second congruent list for a survival scenario, and a third list that contained incongruent words for both scenarios. The result of the study showed that when people processed information under conditions congruent with the list type — for example, survival list in the survival scenario — the recall performance was higher compared to processing information under conditions inconsistent with the list type — for example, survival list in the robbery scenario.

Nairne and Pandeirada (2011), however, observed that the survival processing advantage remains independent of the congruence of the words with the context — robbery or survival — in which this information will be processed. For example, incongruent words for a survival situation, when classified as relevant to survival, are significantly recalled (Nairne & Pandeirada, 2011), indicating that adaptive bias is independent of congruence. In this sense, there is a lot of robust evidence supporting the adaptive memory bias to retrieve important information for survival, and this mnemonic advantage remains in different situations, with different stimuli and against different scenarios (Nairne et al., 2007; Weinstein et al., 2008; Soderstrom & McCabe, 2011; Silva et al., 2019; Moura et al., 2021). However, it remains uncertain whether survival processing advantage is influenced by the better adequacy of information (congruence) in any encoding context (see Nairne & Pandeirada, 2011; Coverdale & Nairne, 2019).

Thus, since cognitive adaptations may have evolved both in different ancestral environments in which hominids originated and evolved (see Moura et al., 2018) and in modern environments (Moura et al., 2021), we aimed to analyzed for the first time if the adaptive bias of memory is influenced by the congruence between the type of processing and the information to be remembered in different evolutionary environments (savannah, deciduous forest and rainforest) and in modern environments. We consider savanna, rainforest, and deciduous forests ancestral environments based on recent paleoanthropological evidence from early human fossils (eg, Roberts et al., 2016; Böhme et al., 2017; Friesem et al., 2017; Hublin et al., 2017; Hublin et al., 2017; al., 2017; Richter et al., 2017; Kong et al., 2018; Zhu et al., 2018).

We analyzed the influence of the congruence between the type of processing (survival or robbery) and the information to be remembered in a dangerous situation related to the use of

medicinal plants in different ancestral and modern environments, in addition to the robbery control scenario — which is a scenario that is not necessarily related to a survival situation — (see Butler et al., 2009). Dealing with diseases using medicinal plants was a recurrent and important challenge for the survival and evolution of hominids in the evolutionary past (see Johns, 1990; Nairne & Pandeirada, 2010; Ferreira Júnior & Albuquerque, 2018; Albuquerque et al., 2020). Using medicinal plants is an interesting model, even to understand how the human naturalistic mind operates. The naturalistic mind is a cognitive structure molded in the ancestral past that influences the way people deal with the natural world (Albuquerque and Ferreira Júnior 2017). For this reason, the adaptive memory bias can be enhanced in this context and facilitate the retrieval of information about medicinal plants. Thus, we tested the following hypothesis: The advantage of survival processing in memory, in dangerous situations involving the use of medicinal plants, remains independent of the congruence of the information with the survival condition and the robbery condition (coding context). Thus, we predict that i) memory performance is higher in the survival condition compared to the robbery condition; and ii) the words classified as most relevant in ancestral and modern survival scenarios are quantitatively more remembered, regardless of the congruence of the information with the encoding context.

2. Material and Methods

2.1 Participants

We recruited 816 volunteers (mean age = 32.2 years; *SD* = 9.36), residing in Brazil, over 18 years, including 64% women and 36% men. The educational level of volunteers was 76% postgraduate, 13.6% complete higher education, 9.6% incomplete higher education, 0.7% complete high school and 0.1% complete elementary education. Volunteers were recruited through the access link to the online survey platform, published on social media (Facebook, Instagram, Twitter and E-mail). Before starting the survey, all candidate participants were instructed to read the Informed Consent Form (TCLE) for their consent.

The Research Ethics Committee involving human beings at the University of Pernambuco approved this study (decision number 4.748.519). All participants read and signed the consent form that explained the research procedures and objectives.

2.2 Experiment and word selection

The company responsible for developing the virtual environment in which the research was carried out was *Quacks Digital Interactivity* (www.quacks.com.br). No survey information was used or shared with other commercial companies.

We designed an experiment, adapted from the work of Nairne et al. (2007) and Butler et al. (2009), to analyze the congruence effect on the survival processing paradigm. We simulated different survival scenarios, in which each volunteer assessed the relevance of information to perform the task of finding and using medicinal plants to treat a disease, recovering later on a surprise recall test. We also used a robbery control scenario, in which we asked volunteers to analyze the relevance of information to a task related to a bank robbery.

The objective was to analyze whether the words congruent with the scenario would be quantitatively more remembered in a surprise test of free recall compared to the words classified as more relevant by the volunteers. For this, we use three different word lists, with 15 words relevant to the survival scenarios (survival list), 15 words relevant to the robbery scenario (robbery list) and 15 irrelevant words for both scenarios (irrelevant list), totaling 45 words that were evaluated by each volunteer.

The words were presented at random, and all volunteers, both in the survival condition and in the robbery condition, evaluated and tried to recall together all the words present in the three lists. Thus, the list type (survival, robbery and irrelevant) was manipulated within the subjects and the type of processing (survival condition and robbery condition) was manipulated among the subjects with 102 subjects in each survival condition and in the robbery condition (see Butler et al., 2009). The 45 selected words that we used as a stimulus, followed by their English translation, are described in Appendix 1. The irrelevant list and robbery words were selected from the study by Butler et al. (2009), and the words in the survival list — which are relevant to the challenge of finding medicinal plants — were selected from the study by Moura et al. (2021), which allowed us to know in advance the relevance of each word. Knowing in advance the relevance of words in relation to the scenario allows testing the congruence effect on mnemonic performance. The same set of 45 words was used for all simulated survival and control scenarios, and the words were randomized before being presented to each participant. In Annex 1 we show the known values of the relevancy of the words. The ranking of word relevance given by the volunteers during the research was measured using a Likert scale, which ranged from 5 for extremely relevant to 1 for extremely irrelevant.

2.3 Survival scenarios

To test the congruence effect on adaptive memory bias, we used simulated survival scenarios that represent dangerous situations (see Nairne et al., 2007; Scofield et al., 2018), covering an urban setting and the six large terrestrial biomes (as classified by Odum, 1989), and a robbery control scenario (see Butler et al., 2009). Thus, the survival scenarios we used encompassed possible ancestral environments of evolution — rainforest, deciduous forests, and savannas — and modern environments — coniferous forests, desert, tundra, and urban (see Moura et al., 2021). The same dangerous situation — needing to treat an illness — was maintained in all survival scenarios. In addition, we displayed an image of the landscape corresponding to the respective environment to each participant so that the situation had another stimulus associated with it. For this, we used seven images used by Moura et al. (2018), and an image representing the physical structure of a bank, taken from the public domain image bank *Pixabay*. In Box 1, we describe the robbery control scenario and one of the simulated survival scenarios.

Box 1 Description of one of the simulated survival scenarios and the robbery scenario, the text of the situation and the corresponding image of the environment (for all eight scenarios used, see Appendix A).

Environment	**Text**	**Image**
Robbery	*Imagine you are leading a robbery of a well-guarded bank. Over the next few days, you'll need to find people to help you, make a plan, and gather all the supplies you might need. We are going to show you a list of words and we would like you to rate the relevance of each of these words to this robbery situation. The relevance scale ranges from one to five, with one (1) meaning the word is totally irrelevant and five (5) meaning extremely relevant. Some of the words may be relevant and some may not, it's up to you to decide.*	

Rainforest	*Imagine that you are alone and sick in a rainforest, with no basic materials for survival. Over the next few days, you will need to find and use medicinal plants to treat this disease. We are going to show you a list of words and we would like you to rate the relevance of each in your attempt to treat the disease and survive in this environment. The relevance scale ranges from one to five, with one (1) meaning the word is totally irrelevant and five (5) meaning extremely relevant. Some of the words may be relevant and some may not, it's up to you to decide.*	

2.4 Procedure

Volunteers were recruited through the access link to the online survey platform and were individually tested in a virtual environment. The volunteers were divided into eight groups (n = 102 in each group) that differed by the type of simulated environment. These environments were considered i) ancestral — rainforest, deciduous forest, and savannah — ii) modern — coniferous forest, desert, tundra, and urban — and the iii) robbery control scenario. The objective was to observe how the congruence effect influences mnemonic performance in ancestral and modern environments, inserting more ancestral and modern scenarios than those generally used in previous studies (eg, Butler et al., 2009; Nairne & Pandeirada, 2011). In the first part of the experiment, a simulated scenario was presented to the participants, and each participant was instructed to rate the relevance (ranging from 1 to 5) of 45 words to survive in the presented survival or robbery situation (Box 1). Each word was displayed on the computer screen for 5 seconds. Then, there was a 2 minute distraction interval, time needed to avoid the tendency to remember the first elements of a list (primacy effect) and the last elements (recince effect), during which the participants filled out a form about demographic data. After that, a surprise test of free recall was performed, in which the participants were instructed to write the maximum number of evaluated words that they could remember, regardless of order, within 10 minutes. The research with each participant lasted approximately 25 minutes.

2.5 Data analysis

To test the hypothesis that the advantage of memory survival processing in dangerous situations involving the use of medicinal plants remains independent of the congruence of information with the encoding context, we performed a Kruskal- Wallis using the R version 3.6.1 environment (R Core Team, 2019). We chose this non-parametric test because from our data we observed that the distribution of residuals was non-normal. The environment and the relevance of the words are independent variables, as they are factors that influence memory in the recall test, with the dependent variable being the recall (proportion of words retrieved) of the words evaluated by the volunteers.

Thus, we compared the proportion of evaluated words recalled, related to each list type and in each condition, among all the survival scenarios and in the robbery control scenario. The performance (proportion) of recall was compared using the test to assess whether there was a significant difference in word recall. After the analysis, a test was performed *post hoc* Dunn to verify where the difference in the proportion of recalled words was. We performed the same test to analyze recall performance across all ancestral and modern scenarios separately.

3. Results

3.1 Performance of recall between lists in the robbery and survival condition

Recall performance was highest in the two conditions — survival and robbery — for which the processing type was congruent with the list type. This result does not support the hypothesis that the advantage of survival processing in memory remains independent of the congruence of information with the encoding context, as memory performance was significant both in the robbery condition (H = 7.334; p <0.03) and in the survival condition (H = 6,337; p < 0.04). This suggests that the congruence effect may also produce retention and recall advantages in memory, not just survival processing. That is, words congruent to a survival situation were remembered more than words inconsistent with this situation.

The *post hoc* Dunn's test showed that, in the robbery control condition, the robbery list ($p < 0.05$) and the survival list ($p < 0.05$) had a significant amount of recalled words. However, the irrelevant list did not perform significantly on recalled words (p >0.05) compared to the other lists. In the survival condition, the survival list ($p < 0.05$) had a significant amount of

recalled words both compared to the robbery list and the irrelevant list (Figure 1). The results of the descriptive analysis of the proportion of words recalled by the participants, in the recall test, for the three types of lists in the robbery and survival condition are presented in Table 1.

Table 1: Differences in medians (Kruskal–Wallis) and descriptive analysis regarding the proportion of words remembered by the participants, in the free recall test, for the three types of lists in the robbery and survival condition.

Free recall							
Processing Condition	***N***	***H***	**List Type**	**Ratio**	**Median**	**Mean**	**Standard Deviation**
Robbery	102	7.334*	Irrelevant	0.28	27	30.33	17.40
			Survival	0.43	47	44.33	11.47
			Robbery	0.48	48	49.26	21.47
Survival	714	6.337*	Irrelevant	0.31	245	231.86	129.93
			Survival	0.46	341	337.26	108.55
			Robbery	0.32	163	232.2	146.71

*$p < 0.05$ (there was a significant difference in word recall).

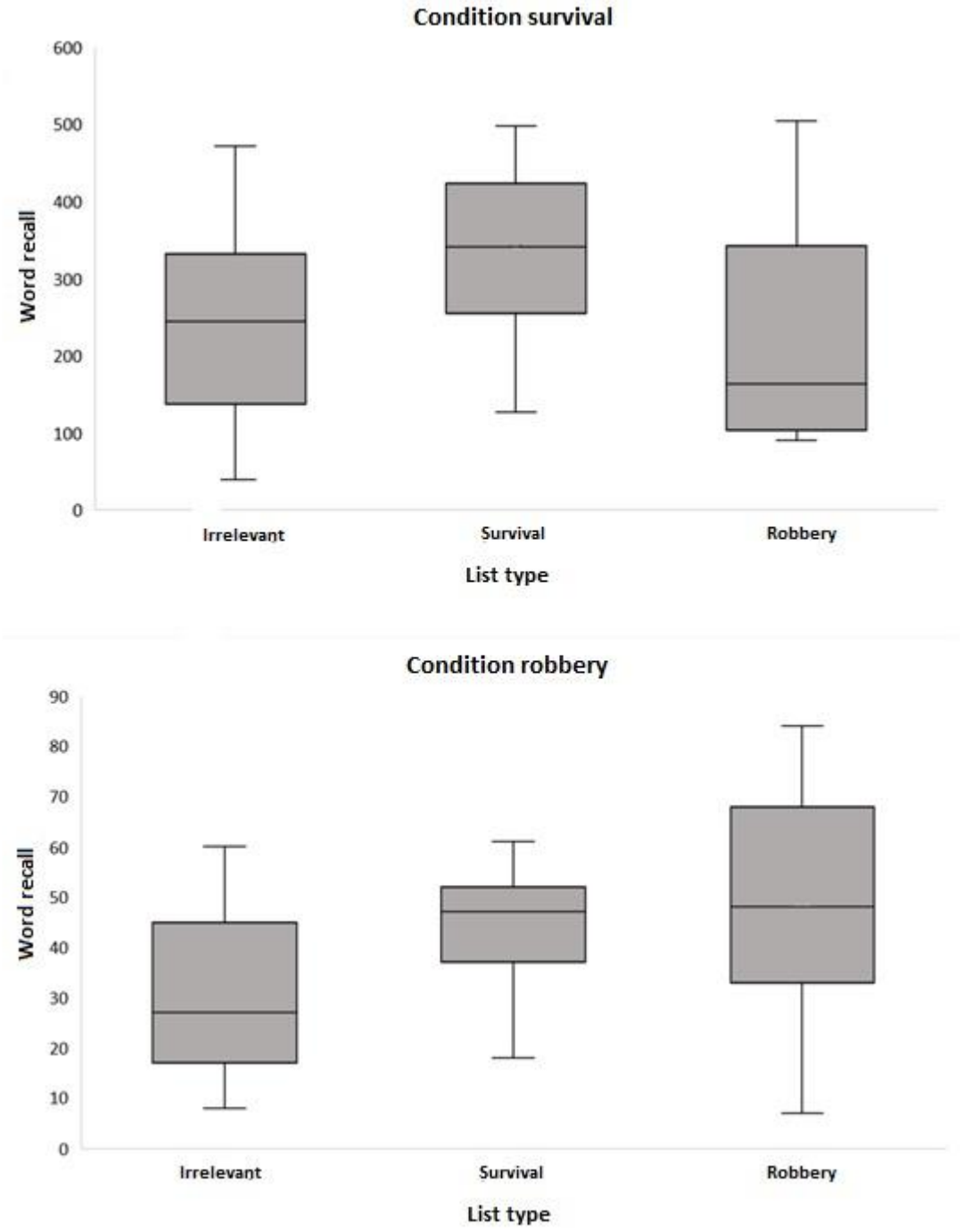

Figure 1. Distribution of the number of words remembered by the participants by list type in the robbery and survival condition. In the survival condition, only the survival list had a significant amount of recalled words ($p < 0.05$). In the robbery condition, the robbery list and the survival list had a significant amount of recalled words ($p < 0.05$) compared to the irrelevant list ($p > 0.05$).

The results of the descriptive analysis of the classification of words for each list in each condition (survival and robbery) of the experiment are described in Table 2 (we also informed the response time of each volunteer when evaluating the words). In Figure 2, we show the correct proportion of words retrieved from the lists in the free recall test as a function of the type of processing condition. The advantage of survival processing in memory was maintained according to the congruence of the information with the encoding context. This suggests that people prioritize in memory the retrieval of information that is congruent with the situation to which they were exposed, whether involving the use of medicinal plants or in situations involving a robbery.

Table 2: Mean, median and standard deviation of word classification and response time for each list in each condition (survival and robbery) of the experiment.

	Condition survival			**Condition robbery**		
List	Irrelevant	Survival	Robbery	Irrelevant	Survival	Robbery
Rating average	1.92	3.79*	2.23	1.72	2.65	4.00*
Median	1	4	1	1	2	5
Standard deviation	1.27	1.39	1.47	1.23	1.62	1.41
Response time average (msec)	3920	3778	3877	3545	3532	3523
Median	2982	2950	3024	2768	2863	2777
Standard deviation	4.48	7.56	3.22	3.01	2.43	2.55

*p <0.05 (there was a significant difference in word classification).

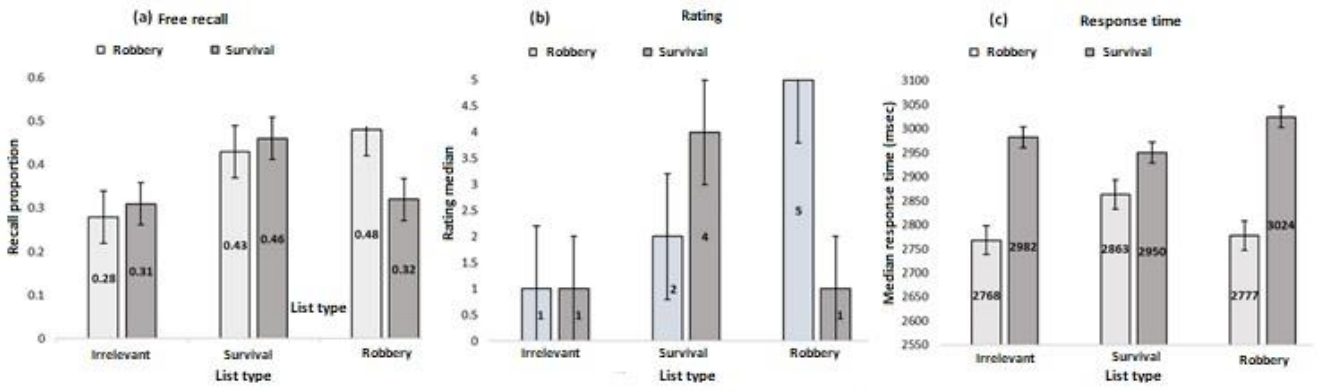

Figure 2: Performance in the Experiment as a function of the type of processing condition. The three panels represent the correct proportion of words retrieved in the free recall test (a), median

word classification (b) and median response time (c), respectively. Error bars indicate 95% confidence intervals.

3.2 Performance of recall between lists in all ancestral and modern settings

We performed an analysis with the environments separately to see if the memory adaptive bias would be influenced by the congruence depending on the ancestral or modern environment, as we predicted in our prediction. The result did not support the hypothesis that the advantage of in-memory survival processing remains independent of the congruence of information with the encoding context, as the performance of recall in ancestral savannah environments ($H = 8.041$; $p < 0.02$) in deciduous ($H = 6400$; $p < 0.04$) and rainforest ($H = 6.283$; $p < 0.04$), and in the modern conifer environment ($H = 7.360$; $p < 0.03$), it was more significant when the type of processing was congruent with the list type (Figure 3). This suggests that people prioritize in memory the retrieval of information that is congruent to the use of medicinal plants in both ancestral and modern environments. The results of the descriptive analysis of the proportion of words recalled by the participants, in the recall test, for the three types of lists in all ancestral and modern environments are described in Table 3.

Table 3: Differences in medians (Kruskal–Wallis) and the descriptive analysis related to the proportion of words remembered by the participants, in the free recall test, for the three list types in the robbery condition and in ancestral and modern environments.

Free recall							
Processing Condition	***N***	***H***	**List Type**	**Ratio**	**Median**	**Mean**	**Standard Deviation**
Robbery	102	7.334*	Irrelevant	0.28	27	30.33	17.40
			Survival	0.43	47	44.33	11.47
			Robbery	0.48	48	49.26	21.47
Rainforest	102	6.283*	Irrelevant	0.32	28	32.46	18.70
			Survival	0.47	47	48.06	17.26
			Robbery	0.31	25	31.80	19.18

Tundra	102	6.046	Irrelevant	0.34	33	35.13	19.68
			Survival	0.48	51	49.26	14.71
			Robbery	0.32	23	33.13	22.22
Savannah	102	8.041*	Irrelevant	0.31	31	31.13	18.61
			Survival	0.47	51	48.86	15.62
			Robbery	0.32	23	32.93	21.36
Desert	102	6.041	Irrelevant	0.31	32	32.06	17.60
			Survival	0.47	54	48.33	17.58
			Robbery	0.33	28	34.53	22.21
Deciduous	102	6.400*	Irrelevant	0.33	39	33.87	18.60
			Survival	0.48	51	49.06	14.54
			Robbery	0.32	24	32.67	22.77
Coniferous	102	7.360*	Irrelevant	0.31	31	32.40	19.80
			Survival	0.48	48	48.93	16.62
			Robbery	0.29	22	30.93	20.45
Urban	102	2.340	Irrelevant	0.34	32	34.80	20.05
			Survival	0.42	44	44.73	17.96
			Robbery	0.34	32	36.20	20.93

*p <0.05 (there were significant difference in word recall)

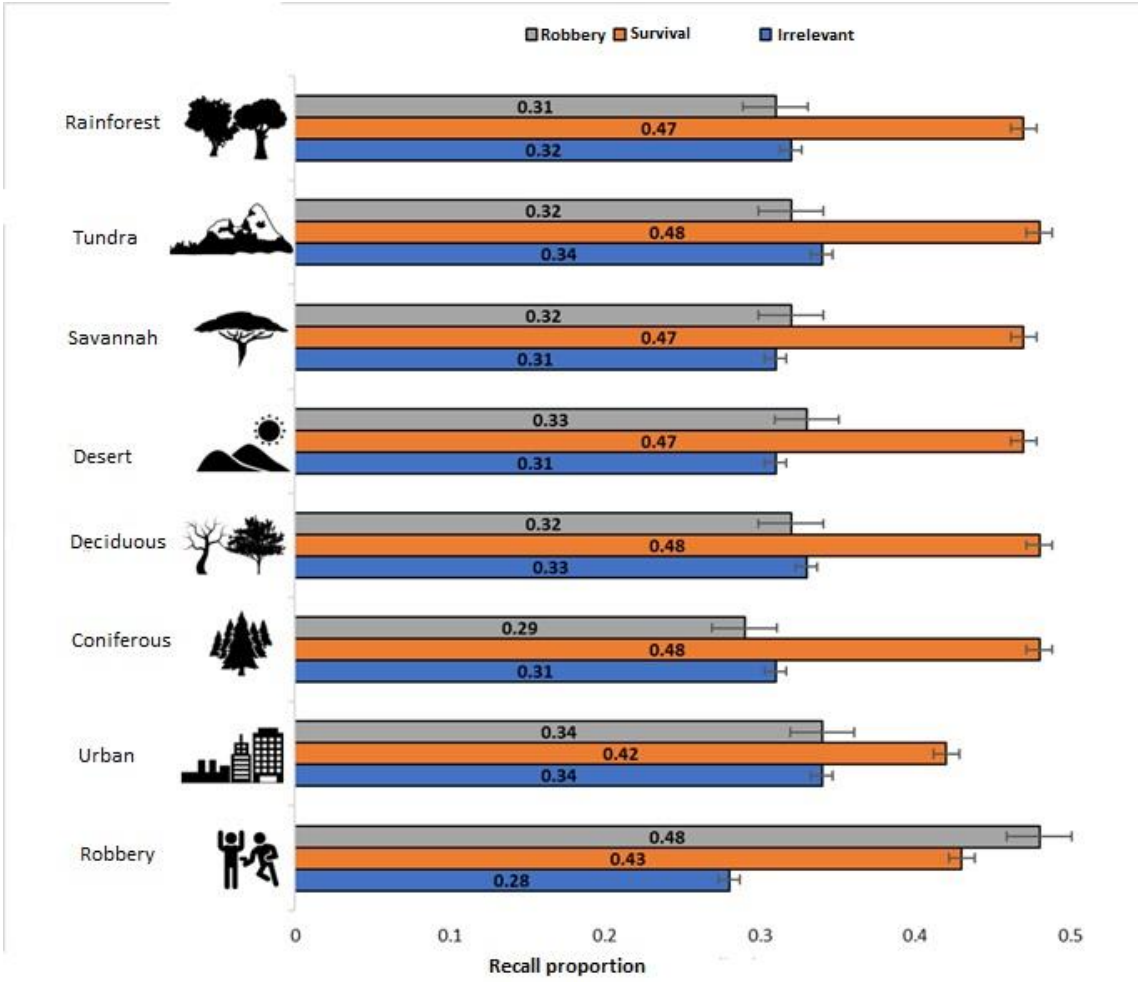

Figure 3. Proportion of correctly retrieved words in the free recall test as a function of the type of list and the type of processing condition in ancestral and modern environments. Error bars indicate 95% confidence intervals.

However, when we grouped and analyzed ancestral environments (savannah, deciduous forest and rainforest) and modern environments (urban, coniferous forest, desert and tundra), recall was significant in ancestral scenarios (H = 7.669; p <0.02), but it was not significant in the clustered modern scenarios (H = 5245; p < 0.07). This suggests that there is an effect of environment type on information recall only when they are analyzed separately.

4. Discussion

In this study, we tested the hypothesis that the advantage of survival processing in memory, in dangerous situations involving the use of medicinal plants, remains independent of the congruence of information with the context of survival encoding. Our results do not support the hypothesis, since memory performance in the free recall test was significant both in the

robbery and in the ancestral and modern survival condition, and the mnemonic advantage was maintained according to the congruence of the information with the context encoding. This suggests that when human beings store in memory information about the use of medicinal plants to treat diseases, both in old and new environments, the retrieval of information that is congruent with each condition tends to be prioritized.

For Butler et al. (2009), the advantage of survival processing tends to disappear when congruence is controlled. However, our results suggest that congruence can potentiate the adaptive memory bias, rather than cancel it out. Despite the information-context congruence having influenced the recall of information in our study, the survival list seems to generate some effect that enhances memory performance, since in the survival condition only it stood out, but in the robbery condition both the robbery and the survival list (which was incongruous with the situation) stood out. Somehow, the advantage of processing survival in a dangerous situation remains even when congruence is controlled (Nairne & Pandeirada, 2011), operating in conjunction with congruence.

One possible explanation is that even information that appears to be irrelevant, such as a bed, can become relevant for survival, as the danger situation forces participants to consider the properties relevant to the fitness of all stimuli presented in a situation of danger (Nairne & Pandeirada, 2011). The same does not happen in a robbery control situation, as it is not a situation that directly involves survival, and perhaps that is why the survival list also stood out in this condition along with the robbery list.

Furthermore, as the irrelevant list — which contained words incongruent for both the robbery and survival conditions — did not stand out in any condition, this evidences that human beings selectively recall information that is congruent and relevant to a given context, while forgetting irrelevant information (Stefanidi, Ellis & Brewer, 2018). However, it is important to analyze whether congruence enhances recall in any context, since recovery advantages related to incongruent stimuli can occur. For example, a study by Sandry and Ricker (2020) showed that if, while people are looking at a set of black geometric images, and incongruous red image appears, attention is directed to this image if there is a better reward for looking at it. For Sandry and Ricker (2020), depending on the reward, the attention directed to a stimulus can be flexible and prioritize incongruity, making this stimulus easily coded.

The fact that in our study the survival list also stands out in the robbery condition suggests that even in a situation that does not directly involve survival, the human mind is flexible to direct attention to important information for robbery, but also to pay attention to survival. For example, it has been shown that paying attention to negative information (eg,

untrustworthy faces) helps people avoid potential threats to survival and this was important in the evolutionary past, however, paying attention to trustworthy faces is also important as they offer results social desirables (Hou & Liu, 2019). This attentional flexibility can influence the way we store and retrieve in memory both information directly related to survival situations and other information important to our social well-being (see Hou & Liu, 2019). This view fits the idea proposed by Sandry et al. (2013), in which an adaptive memory system must have evolved to be sensitive to the demands of the environment, flexibly adjusting to different conditions and functioning hierarchically.

In this sense, it is likely that the human mind operates through flexible strategic processes (Fiedler, Bluemke & Unkelbach, 2011). From an evolutionary perspective, working sensitively to environmental stimuli and generating flexible responses may have given early hominids the ability to adaptively deal with different and recurring ancestral challenges — whether fleeing a predator or interacting with a friend. Thus, adaptive memory bias is an evolved psychological mechanism that can produce varied and flexible behavioral responses in response to varied environmental contexts (see Lewis et al., 2020). The flexibility of memory, therefore, may have been reflected in our results, as there was a significant performance in recalling information related to the use of medicinal plants in both ancestral and modern environments.

For Nairne and Collaborators (2007), the memory system of human beings is adaptive and performs better when it operates related to relevant ancestral contexts, such as the savannah. For example, the ancestral scenario encourages people to generate significantly more alternative uses of words compared to the bank robbery condition (see Wilson, 2016). However, based on our results, we argue that the mnemonic benefit, enhanced by congruence, is not restricted to the ancestral savannah environment, encompassing other evolutionary environments — such as rainforest and coniferous forest — and more modern environmental configurations. In this sense, human beings may have developed a memory system that operates by activating general domain processes (Nairne & Pandeirada, 2016; see also Smith, 2020), which respond to ancient and recent environmental configurations (Yang et al., 2014). Furthermore, other immediate processes in memory can influence recall and should be analyzed. For example, information relevant to dealing with a single survival problem (finding water) is less recalled than information related to a scenario involving multiple survival problems — such as avoiding a predator, finding water and food. In this case, the richness of coding offered by these scenarios, which involve several challenges, can leverage the advantage of survival processing (Kroneisen & Erdfelder, 2011).

5. Conclusion

Information-context congruence is an important immediate mechanism that enhances mnemonic performance and should be considered in studies that analyze processing levels in the human mind. However, we emphasize that the advantage of survival processing occurs even when congruence is controlled. This happens because memory works in a hierarchical way, giving importance to the congruence of information, but also considering the survival factor.

In this sense, human beings store and retrieve in memory congruent and important information to search for and use medicinal plants to treat diseases, both in ancestral and modern environments. Human memory, therefore, can operate in a stimuli-sensitive and flexible way, generating adaptive responses according to the demands of the environment.

Conflict of Interest Statement

None.

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Appendix A

Description of the simulated robbery and survival scenarios, texts of the situations and the respective images of the environments.

Environment	Text	Image

Robbery	*Imagine that you are leading a robbery of a well-guarded bank (image above). Over the next few months, you'll need to find people to help you, make a plan, and gather all the supplies you might need. We are going to show you a list of words and we would like you to rate the relevance of each of these words to you in this robbery situation. The relevance scale ranges from one to five, with one (1) meaning the word is totally irrelevant and five (5) meaning extremely relevant. Some of the words may be relevant and some may not, it's up to you to decide.*	
Coniferous forest	*"Imagine that you are alone and sick in a coniferous forest, with no basic materials for survival. Over the next few days, you will need to find and use medicinal plants to treat this disease. We are going to show you a list of words and we would like you to rate the relevance of each in your attempt to treat the disease and survive in this environment. The relevance scale ranges from one to five, with one (1) meaning the word is totally irrelevant and five (5) meaning extremely relevant. Some of the words may be relevant*	

	and others not, it's up to you to decide."	
Deciduous forest	*"Imagine that you are alone and sick in a deciduous forest, without basic materials for survival. Over the next few days, you will need to find and use medicinal plants to treat this disease. We are going to show you a list of words and we would like you to rate the relevance of each in your attempt to treat the disease and survive in this environment. The relevance scale ranges from one to five, with one (1) meaning the word is totally irrelevant and five (5) meaning extremely relevant. Some of the words may be relevant and others not, it's up to you to decide."*	
Desert	*"Imagine you are alone and sick in a desert, with no basic materials for survival. Over the next few days, you will need to find and use medicinal plants to treat this disease. We are going to show you a list of words and we would like you to rate the relevance of each in your attempt to treat the disease and survive in this environment. The relevance scale ranges from one to five, with one (1) meaning the word is totally irrelevant and five (5) meaning extremely relevant. Some of the*	

	words may be relevant and others not, it's up to you to decide."	
Savannah	*"Imagine you are alone and sick in a savannah, without basic materials for survival. Over the next few days, you will need to find and use medicinal plants to treat this disease. We are going to show you a list of words and we would like you to rate the relevance of each in your attempt to treat the disease and survive in this environment. The relevance scale ranges from one to five, with one (1) meaning the word is totally irrelevant and five (5) meaning extremely relevant. Some of the words may be relevant and others not, it's up to you to decide."*	
Rainforest	*"Imagine you are alone and sick in a rainforest, with no basic materials for survival. Over the next few days, you will need to find and use medicinal plants to treat this disease. We are going to show you a list of words and we would like you to rate the relevance of each in your attempt to treat the disease and survive in this environment. The relevance scale ranges from one to five, with one (1) meaning the word is totally irrelevant and five (5) meaning extremely relevant. Some of the*	

	words may be relevant and others not, it's up to you to decide."	
Tundra	*"Imagine that you are alone and sick in a tundra, with no basic materials for survival. Over the next few days, you will need to find and use medicinal plants to treat this disease. We are going to show you a list of words and we would like you to rate the relevance of each in your attempt to treat the disease and survive in this environment. The relevance scale ranges from one to five, with one (1) meaning the word is totally irrelevant and five (5) meaning extremely relevant. Some of the words may be relevant and others not, it's up to you to decide."*	
Urban	*"Imagine you are alone and sick in a city, without basic materials for survival. Over the next few days, you will need to find and use medicinal plants to treat this disease. We are going to show you a list of words and we would like you to rate the relevance of each in your attempt to treat the disease and survive in this environment. The relevance scale ranges from one to five, with one (1) meaning the word is totally irrelevant and five (5) meaning extremely*	

	relevant. Some of the words may be relevant and others not, it's up to you to decide."	

Annex 1

Average relevance rating of words from the three lists used in the experiment (robbery, survival and irrelevant)

	Average relevance rating for robbery
List robbery (words)	
Account	4.0
Alarm	4.7
Car	4.9
Case	4.3
Employee	4.7
Code	4.9
Computer	4.6
Warehouse	4.0
Door	3.9
Mask	4.6
Telephone	3.7
Safe	4.9
Window	4.1
Wire	4.1
Witness	4.7
List Mean	**4.4**

Annex 1 (continued)

	Average Survival Relevance Rating Survival
List (Words)	
Blood	4.0
Water	4.8
Nature	4.7
Medicine	4.7
Vitamin	4.5
People	4.4
Fire	4.1
Animal	3.9
Shirt	3.9
Landscape	3.6
Needle	3.4
Cotton	3.1
Sofa	3.0

Bedding	3.1
Bag	3.0
List Average	**3.88**

Annex 1 (continued)

	Average Relevance Rating for Robbery and Survival Scenario	
Irrelevant List (Words)	**Survival**	**Robbery**
Sofa	1.1	1.0
Flute	1.0	1.0
Girl	1.6	1.7
Horn	1.9	1.3
Husband	1.3	1.0
Inch	1.0	1.6
Jazz	1.0	1.0
Nation	1.1	1.6
Photography	1.0	1.6
Rake	1.6	1.0
Football	1.1	1.0
Spoon	1.6	1.0
Student	1.1	1.1
Table	1.1	1.7
Tulip	1.3	1.0
Average of the list	**1.3**	**1.2**

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CAPÍTULO 4: CONSIDERAÇÕES FINAIS

4.1 PRINCIPAIS CONCLUSÕES

A análise, nessa tese, do desempenho da memória adaptativa em diferentes tipos de ambientes ancestrais e modernos, foi essencial para evidenciar a flexibilidade da mente naturalista humana e como isso afeta a relação das pessoas com a natureza. De maneira específica, nossos achados evidenciam que a mente naturalista humana é flexível para lidar com desafios relacionados ao uso de plantas medicinais em diferentes contextos ambientais. Ao que tudo indica, os diferentes ambientes que os primeiros hominídeos habitaram durante a história evolutiva pode ter influenciado a evolução de uma mente pouco rígida e sensível às demandas do mundo natural, sejam elas relacionadas a savana, floresta tropical, ou ambientes mais recentes habitados pelos humanos, como tundra e ambientes urbano. Além disso, fatores imediatos, como o efeito de congruência, podem exercer influência sobre vieses cognitivos moldados no passado ancestral — nesse caso, sobre o viés adaptativo da memória.

Acreditamos que lidar com desafios em diferentes locais foi importante para nossa evolução, uma vez que o uso de plantas medicinais, por exemplo, foi imprescindível para nossa sobrevivência, e saber lidar com esse recurso, independente da configuração ambiental em que ele se encontra, ajudou os primeiros humanos a sobreviver e reproduzir.

Por fim, de maneira geral, nossa tese evidenciou que: as pessoas se lembram de informações importantes a sobrevivência independente do contexto ambiental em que os desafios ocorrem, além de que a capacidade de lembrar essas informações não está exclusivamente ligada às prioridades ancestrais, e que somos dotados de uma mente naturalista capaz de processar informações sobre o mundo natural.

4.2 CONTRIBUIÇÕES TEÓRICAS E/OU METODOLÓGICAS DA DISSERTAÇÃO/TESE

A nossa tese tem duas contribuições teóricas principais. Primeiro, mostramos que a mente humana é flexível e não está restrita a savana ou a outro ambiente específico. Depois, mostramos que a congruência não anula a vantagem do processamento de sobrevivência, mas o potencializa.

Muitos estudos em psicologia evolucionista destacam o papel da savana e de suas pressões seletivas recorrentes na evolução dos mecanismos psicológicos evoluídos. Todavia, evidências paleoantropológicas mostram que os humanos habitaram, durante o Pleistoceno,

uma ampla gama de ambientes e isso refletiu em nossos resultados. Talvez os seres humanos tenham esse aparente sucesso evolutivo pelo fato de responderem adaptativamente a desafios em vários locais. Assumimos, porém, que nem todos os psicólogos evolucionistas defendem a existência de uma mente humana rígida, mas é um debate que precisa avançar, e analisar os vieses evolutivos a partir do uso dos recursos naturais em diferentes contextos parece ser promissor tanto para o avanço da PE quanto, principalmente, para a etnobiologia evolutiva.

Além disso, nossa tese contribui metodologicamente ao mostrar que a congruência entre a informação e o contexto de codificação, quando não controlada, pode influenciar a vantagem do processamento de sobrevivência na memória. Sugerimos que esse fator seja considerado em estudos que analisam o paradigma da sobrevivência e outros níveis de processamento da memória.

4.3 PRINCIPAIS LIMITAÇÕES DO ESTUDO

Em relação ao produto do segundo capítulo da tese, a principal limitação foi que o desempenho da memória não foi comparado a uma condição de controle — por exemplo, um cenário "móvel" normalmente utilizado em estudos que analisam a memória adaptativa. Sem esse controle, é difícil entender se o desempenho mnemônico foi realmente bom ou ruim entre os ambientes ancestrais e modernos, o que limita nossa interpretação dos resultados.

Outra limitação relacionada tanto ao produto do segundo capítulo quanto ao produto do terceiro capítulo é o fato de analisarmos o efeito da vantagem do processamento de sobrevivência sobre o uso de plantas medicinais em pessoas que não têm contato contínuo com este tipo de desafio ou uma dependência deste recurso natural. Acreditamos que, de alguma maneira, analisar como a mente opera para lidar com desafios simulados recrutando pessoas que não lidam com esses desafios no mundo real pode limitar o alcance dos nossos resultados.

4.4 PROPOSTAS DE INVESTIGAÇÕES FUTURAS

Em primeiro lugar, sugerimos que investigações futuras utilizem protocolos ajustados para testar a memória adaptativa em sistemas socioecológicos reais, nos quais a população já enfrentou um evento desafiador em algum momento ou que lida com determinado desafio de forma relativamente diária. Além disso, uma vez que em nosso estudo simulamos apenas o

desafio de utilizar plantas medicinais, sugerimos o uso de outros desafios importantes no passado ancestral, como caçar e procurar alimentos.

Com base nos achados do produto do capítulo três, sugerimos que estudos futuros analisem se outros fatores imediatos, além do efeito de congruência, influenciam o viés adaptativo da memória, como a *riqueza de codificação* — ou seja, a quantidade de desafios existentes em cenários de sobrevivência simulados.

Por fim, com base em nosso artigo de revisão de literatura, sugerimos que pesquisas futuras considerem o conhecimento prévio sobre o uso de plantas medicinais para tratar doenças, ou o contato com outro recurso natural, como um fator que pode influenciar o desempenho da memória em testes de recordação.

4.5 ORÇAMENTO

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As despesas para coleta dos dados incluem a compra de material de papelaria (resma de papel A4, cartuchos de impressora e caneta esferográfica), alimentação e transporte (passagem de ônibus para locomoção), totalizando R$8,860,00 em 160 dias de coleta. Para a construção do ambiente virtual para coletar os dados referentes ao produto do terceiro capítulo, foram gastos R$580,00.

Durante o período da coleta de dados, foram selecionados 210 voluntários presencialmente e 816 voluntários remotamente. Assim, o custo estimado para a realização da coleta de dados pode estar subestimado, pois não inclui o tempo gasto na digitalização e planilhamento das informações prestadas pelos voluntários nos experimentos nem a organização de banco de dados.

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ANEXOS

ANEXO 1

PARECER CONSUBSTANCIADO DO CEP

DADOS DA EMENDA

Título da Pesquisa: A evolução de estratégias cognitivas humanas para resolver desafios do ambiente

Pesquisador: Joelson Moreno Brito de Moura

Área Temática:

Versão: 6

CAAE: 97410718.0.0000.5207

Instituição Proponente: UNIVERSIDADE FEDERAL RURAL DE PERNAMBUCO

Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 4.748.519

Apresentação do Projeto:

Trata-se de uma emenda. O presente projeto de pesquisa parte do esforço de tentar entender como amente naturalista opera na espécie humana. Para isso, serão recrutados 1000 estudantes de graduação da Universidade Federal de Pernambuco e 750 estudantes da Universidade Federal Rural de Pernambuco através de entrevistas. A justificativa para a emenda é que a parte final da coleta de dados foi prejudicada pela pandemia, sendo necessário estender a coleta de dados para o ano de 2021.

Objetivo da Pesquisa:

Objetivo geral

- Analisar como a mente naturalista mobiliza estratégias cognitivas na espécie humana para resolverdesafios relacionados a sobrevivência em ambientes ancestrais e modernos.

Objetivos específicos:

- Analisar as estratégias cognitivas mobilizadas na memória para identificar os

desafios relacionados àsaúde humana em ambientes ancestrais e modernos;
- Verificar as estratégias cognitivas mobilizadas na memória para identificar os desafios relacionados àalimentação humana em ambientes ancestrais e modernos;
Analisar as estratégias cognitivas mobilizadas na memória para resolução dos desafios relacionados à procura de plantas medicinais em ambientes ancestrais e modernos;
- Verificar as estratégias cognitivas mobilizadas na memória para resolução dos desafios relacionados àprocura de alimentos em ambientes ancestrais e modernos.

Avaliação dos Riscos e Benefícios:

Quanto aos riscos e desconfortos, o maior risco é o de sentir-se constrangido devido ao teste de memória. Caso o participante venha a sentir algo dentro desses padrões, o mesmo será orientado a abandonar a pesquisa e suas informações não serão utilizadas ou divulgadas. Além disso, caso a conexão com a internetseja interrompida, o participante pode abandonar a pesquisa, não precisando realiza-la novamente e seus dados não serão utilizados ou divulgados.
Os benefícios esperados com o resultado desta pesquisa são que com base nas informações oferecidas, será possível compreender como vieses cognitivos influenciam o comportamento e a relação das pessoas com a natureza.

Comentários e Considerações sobre a Pesquisa:

vide conclusão.

Considerações sobre os Termos de apresentação obrigatória:

vide conclusão.

Conclusões ou Pendências e Lista de Inadequações:

Emenda aprovada.

Considerações Finais a critério do CEP:

O pleno acompanha o parecer do relator.

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BASICAS_1688812_E1.pdf	03/05/2021 16:59:11		Aceito
Projeto Detalhado / Brochura Investigador	projetoJoelsonDoc.docx	03/05/2021 16:58:42	Joelson Moreno Brito de Moura	Aceito
Cronograma	cronogramaComite.docx	03/05/2021 16:58:12	Joelson Moreno Brito de Moura	Aceito

TCLE / Termos de Assentimento / Justificativa de	tcle18anos.docx	19/03/2021 11:34:11	Joelson Moreno Brito de Moura	Aceito

Ausência	tcle18anos.docx	19/03/2021 11:34:11	Joelson Moreno Brito de Moura	Aceito
Outros	formularioPesquisa.docx	19/03/2021 11:29:42	Joelson Moreno Brito de Moura	Aceito
Outros	CartaJustificativaEmenda.doc	13/01/2021 10:54:24	Joelson Moreno Brito de Moura	Aceito
Outros	termoConfidencialidade.pdf	30/08/2018 16:28:13	Joelson Moreno Brito de Moura	Aceito
Outros	lattesUPA.pdf	30/08/2018 16:27:15	Joelson Moreno Brito de Moura	Aceito
Outros	lattesTALINE.pdf	30/08/2018 16:26:54	Joelson Moreno Brito de Moura	Aceito
Outros	lattesWASH.pdf	30/08/2018 16:26:37	Joelson Moreno Brito de Moura	Aceito
Outros	lattesJOELSON.pdf	30/08/2018 16:24:03	Joelson Moreno Brito de Moura	Aceito
Outros	cartaAnuencia2.pdf	30/08/2018 16:23:15	Joelson Moreno Brito de Moura	Aceito
Outros	cartaAnuencia.pdf	30/08/2018 16:22:40	Joelson Moreno Brito de Moura	Aceito
Orçamento	Orcamento.docx	19/07/2018 11:27:18	Joelson Moreno Brito de Moura	Aceito
Folha de Rosto	folhaDeRosto.pdf	19/07/2018 11:24:37	Joelson Moreno Brito de Moura	Aceito

Situação do Parecer:

Aprovado

Necessita Apreciação da CONEP:

Não

RECIFE, 01 de Junho de 2021

Assinado por:

BIANCA MARIA VASCONCELOS VALERIO

(Coordenador(a))

ANEXO 2

Evolutionary Biology

https://doi.org/10.1007/s11692-020-09491-0

Evolutionary Biology
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ESSAY

Theoretical Insights of Evolutionary Psychology: New Opportunities for Studies in Evolutionary Ethnobiology

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Abstract
In this article, we present the central ideas of evolutionary psychology, and discuss how their assumptions can help ethnobiologists to understand the dynamic relationship between people and their environments. In this sense, investigating this relationship from an evolutionary perspective can bring new empirical evidence about human evolution, also contributing to both evolutionary psychology and evolutionary ethnobiology.

Keywords Adaptive memory · Hierarchical memory · Human evolution · Naturalist mind · Social-ecological systems

Introduction

During their evolutionary history, humans have had to interact with their environment, both to capture resources and to avoid threats. This interaction, studied by many scientific fields, may have strongly influenced hominid evolution, such that the relationship between people and nature could be mediated by biases and behaviors shaped in the evolutionary past (see Albuquerque and Ferreira Júnior 2017).

In this regard, a recently developed interdisciplinary field called Evolutionary Ethnobiology (EE) is concerned with understanding how ecological and evolutionary processes influence people's cognition and behavior in relation to their environments (Albuquerque, Medeiros and Casas 2015). To this end, EE promotes the integration and systematization of evolutionary concepts from Cultural Evolution, Genetics, Evolutionary Psychology (EP) among others (Albuquerque and Ferreira Júnior 2017). However, this integration is recent, and little is known regarding how evolutionary biases may operate in the dynamic relationship between humans and nature. The basic premise of EE is that selective pressures during human evolution, associated with the need to have a relationship with the environment in order to survive, have spawned in humans a naturalistic mind that involves a complex cognitive structure that influences the way people perceive and seek to understand the natural world (Albuquerque and Ferreira Júnior 2017). Thus, we believe that ethnobiological studies that fail to take evolutionary biases into account in their hypotheses may fail to completely capture a given phenomena.

One practical example might be data collection in ethnobiological studies. For Albuquerque and Ferreira Júnior (2017), ethnobiological studies that collect empirical data in real systems are actually retrieving data stored in individual memories, and few studies in ethnobiology recognize memory as a bias in data collection. Thus, a key element is to understand how memory can influence the collection and interpretation of information obtained in social-ecological

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systems.[1] At this point, the concept of *adaptive memory* addressed in evolutionary psychology seems to be fundamental, since it assumes that humans tend to prioritize in memory information of greater adaptive value that are relevant for survival (Nairne et al. 2007). If this is true, it is imperative that ethnobiological studies consider memory mechanisms shaped in the evolutionary past in their data collections, since, for example, medicinal resources highly recalled by individuals from a certain community may contain therapeutic characteristics that are advantageous for survival.

Moreover, a recent study by Silva et al. (2019) noted that the human mind tends to remember information about frequent illnesses or when they are related to previous experiences of the individual with a given illness. Considering the ancestral context, this might reflect adaptations that were important for hominid survival—helping them remember, for instance, dangerous places or the location of food and water—and that persist to this day in human populations (see Nairne et al. 2007).

Although we believe that humans have genetically inherited behavioral tendencies shaped by their ancestral past, these tendencies can be modified, expressed, or silenced according to the environmental context (see Barrett 2012). However, this genetic heritage cannot be ignored, and it seems to precede behavior. For example, for the behavioral complexity of human societies to emerge and increase over time, certain innate mental faculties, genetically selected in some ancestral environment, have to be present—such as the ability to imitate—making cultural evolution possible (see Stanford 2019).[2] Therefore, investigating the evolutionary aspects behind the decisions and behavior of humans regarding nature seems crucial. For this, Evolutionary Psychology shows promise for our understanding the mechanisms operating in this relationship.

Accordingly, the main goal of this article is to demonstrate how Evolutionary Psychology's assumptions can help us discern the complex and dynamic relationship of people and their environments, and particularly what influences their decisions. This is only possible by understanding the evolutionary roots preceding behavior. To this end, we present the theoretical scenario of EP and its applications for studies in the EE field's First, we introduce and describe the key concepts of EP. Then we explain the concept of adaptive memory (an important concept) and how it is empirically tested. Lastly, we bring insights and examples that may guide future studies that seek to use an evolutionary perspective to understand the relationship between people and the biota. This first theoretical effort can help to promote a productive integration with EE.

A Brief Introduction to Evolutionary Psychology

Evolutionary Psychology is concerned with understanding the functioning of the human mind by analyzing it as the product of natural selection (Buss 1990; Breyer 2015). Thus, it is a functionalist approach—it investigates the functions of the mind. The theoretical trend that most influenced EP was Sociobiology. According to Wilson (1975), the creator of this scientific field, Sociobiology can be defined as the systematic study of the biological basis of animal behavior. From its conception, Sociobiology aimed to create standardized models to understand animal behavior from an evolutionary perspective and expanded this plan to social behavior; in contrast, EP is known for being designed to exclusively understand the psychological mechanisms that precede human behavior (see Breyer 2015). Evolutionary psychologists criticized the neglect of sociobiology with the psychological mechanisms molded in paleoenvironments, and proposed another level of explanation for human nature, giving less attention to human behavior and focusing on the adaptations that allow its expression, in this case, the evolved psychological mechanisms (Hattori and Yamamoto 2012).

Even though sociobiology and EP share the view that human beings evolved through the process of natural selection, the two domains differ in some fundamental respects. For example, according to Buss (1990, 1995), in sociobiology humans have developed adaptations that always aim to maximize their *inclusive fitness*—the ability to, in addition to leaving fertile offspring, the individual also has parental care, since their relatives also carry copies of their genes. Conversely, in EP fitness maximization does not exist because, in principle, natural selection would not have created mechanisms that directed human beings to live for the purpose of leaving descendants in any situation. Some evolutionary psychologists call this idea a "sociobiological fallacy" (Buss 1990). Thus, for many scholars EP is a type of sociobiology, however, less controversial because it is less deterministic, since the mental adaptations shaped by natural selection can be expressed or not in the current environment (see Buss 1990).

EP seeks explanations from the pressures that shaped the human mind in the evolutionary past to solve specific problems connected with the survival and reproduction

[1] Social-ecological systems represent a product of the interaction between sociocultural systems—the set of beliefs, knowledge and behaviors in human groups—and ecological systems—the biotic and abiotic environment of human groups (Berkes and Folke 2000).

[2] Cultural evolution is a scientific field that analyzes changes detected in societies from the perspective of Darwinian evolution theory, and that takes into account such aspects as variation, competition, and inheritance (Mesoudi 2011, 2016).

of the species. In this sense, EP represents a theoretical scenario that integrates aspects of cognitive evolution, the idea that the brain is an information processor of the environment and it relates to evolutionary biology, that like other organs of the human body, understands that the brain has also been the target of natural selection and molded to process one set of information from the environment to the detriment of others (Tooby and Cosmides 1992). It is a relatively recent scientific field, emerging in the early twentieth century and gaining visibility in the 1970s and 1980s.

Although EP is a relatively new academic discipline, functionalist approaches in psychology are ancient, such as in the case of functional psychology, created by William James in the late 19th century, although it has not developed a solid theoretical basis (Gangestad and Tybur 2016). A group of researchers started a series of theoretical and empirical studies (Cosmides and Tooby 1987; Symons 1987; Buss 1989; Cosmides 1989; Barkow et al. 1992) in order to understand the nature and functioning of the human mind, mainly in relation to human preferences in the selection of partners. Among the authors who contributed the most to the popularization and expansion of the EP, we can mention Leda Cosmides, John Tooby, Donald Symons, Jerome Barkow and David Buss.

Since then, EP has progressively gained the attention of important scientific areas that analyze the evolution of human behavior. The field of political science, for example, has published studies on how people's political opinions can be affected by behaviors linked to the ancestral past (see Edwards 2003; Brown 2013; Kubinskia et al. 2018; Petersen 2018). The *marketing* area also brought interesting empirical findings about how human consumption patterns are influenced by evolutionary factors (ver Saad and Gill 2000; Hartmann and Apaolaza-Ibáñes 2010, 2013; Hasford et al. 2018). Table 1 shows some fields of research interest in EP.

The EP studies are based on the essential premise that a lot of human psychological mechanisms are evolved as a result of the selective pressures that hominids were subjected to in the Pleistocene (Buss 1995). Similar to the other organs of the human body, the underlying information processing mechanisms localized in the brain are biological adaptations that enabled the survival and reproduction of early hominids (Buss 1990; Klasios 2016). Thus, the human mind functions in a similar way to a computational system, designed by natural selection to solve adaptive problems faced by our ancestors (Tooby and Cosmides 2015), and that due to this human behave adaptively (Klasios 2016). This evolutionary perspective was a great novelty for researches in psychology that formerly attempted to commonly understand human behavior only influenced by the current historical and social context. However, this new approach has generated some theoretical confusion due to its similarity to sociobiology and, especially, to the concept of modularity of mind (see next section) (Townsend and Barton 2018).

Based on these premises, some essential concepts were created that lead to the majority of research on EP (see Bolhuis et al. 2011), which are summarized in the next session. It is worth noting that these concepts are, to some extent, criticized by some scientists. Thus, we also describe some of these criticisms and alternative views.

Basic Concepts of Evolutionary Psychology

Assuming that humans behave adaptively only makes sense if we assume that there were one or more environments that promoted such adaptations. Thus, the EEA concept argues that our psychological mechanisms evolved in response to the stable characteristics of EEAs (Tooby and Cosmides 2015) present, for example, in African savanna and Pleistocene rainforest environments. However, its first version of the concept was widely criticized, since only savannah was considered an EEA (see Bolhuis et al. 2011). The recent concept of EEA is broad and less specific, which considers all relevant selective environments of the ancestral past (see Tooby and Cosmides 2015).

Thus, EEA is not limited only to the African Pleistocene savanna (see Tooby and Cosmides 2015). In this sense, hominids may have developed psychological mechanisms in different environments during their evolution in the Pleistocene, in a period before or after their settlement in the savannah (see Hartmann and Apaolaza-Ibáñes 2010; Moura et al. 2018).

Modularity of the Mind

The human mind consists of specific domain modules that evolved to solve distinct adaptive problems that arose in the ancestral past (Tooby and Cosmides 2015). For example, modules linked to the detection of cheaters, cooperation, identification and escaping from predators, among others. According to Townsend and Barton (2018), we inherit the specific modules of our ancestors. For example, it was extremely important for early hominids to identify and avoid poisonous animals, such as snakes and spiders, so that, over time, natural selection favored individuals capable of detecting such threats. This may explain even the current phobia behavior of humans in relation to these animals (for a more complete argument, see Tooby and Cosmides 2015). In addition, the ability to memorize information that helps to survive in environments similar to the Pliestocene savanna seems to be a psychological mechanism of extreme importance (see Nairne et al. 2007).

Other psychological mechanisms documented in the literature are: facial recognition of relatives, fear of spiders,

Table 1 Some fields of interest in evolutionary psychology.

Fields of interest	Purpose	Some publications
Cognition and human behavior	Understanding the factors that influence the evolution of cognition and human behavior	Stevenson et al. (2014), Roberts (2015), Roos et al. (2016), Ferera et al. (2018) and Wilke and Todd (2018)
Religious behavior	Understand the influence of natural selection on religious behavior	Boyer and Bergstrom (2008), Leathers and Raines (2014), Franek (2016) and Smail (2018)
Political theory	Understand how people's political views can be affected by behaviors linked to the evolutionary past	Edwards (2003), Brown (2013), Kubinskia et al. (2018) and Petersen (2018)
Evolution of art	Understand the role of art in the evolutionary history of human beings	Sugiyama (1996), Hagen and Bryant (2003), Honing and Ploeger (2012) and Sütterlin et al. (2014)
Economy	Analyze the evolution of the economic logic of human beings	Hoffman et al. (1998); Li et al. (2012), Lawrence and Pirson (2015) and King (2018)
Human preferences	Analyze how the evolutionary past shaped the preferences of human beings. For example, preference for landscape and objects	Altman et al. (2016), Balling and Falk (1982), Orians and Heerwagen (1992), Li et al. (2013), Bøggild and Laustsen (2016) and Townsend and Barton (2018)
Marketing	Identify patterns of human consumption	Holbrook and O'Shaughnessy (1984), Saad and Gill (2000), Hartmann and Apaolaza-Ibáñes (2010, 2013) and Hasford et al. (2018)
Sexual selection and gender differences	Understand the influence of gender difference in mate selection	Buss et al. (1992), Buss and Schmitt (1993), Schwarz and Hassebrauck (2012), Conroy-Beam and Buss (2018), DeLecce et al. (2017) and Jeffery et al. (2018)
Human emotions	Understand how natural selection has shaped emotions over time	Tooby and Cosmides (1990), Al-Shawaf et al. (2016), Klasios (2016) and Eisend (2018)

sexual attraction by partners who demonstrate gentleness and intelligence, detection of cheaters in everyday situations, possible preference for environments that are similar to savannah, among others (see Townsend and Barton 2018; Buss 1995; Tooby and Cosmides 2015). However, among the concepts of psychology this is the most controversial.

According to Bolhuis et al. (2011), there is evidence of neuroscience that does not corroborate the existence of modularity. For example, there is evidence that animals learn and establish causal relationships among a wide variety of events, and this is only possible if the mind is not modular (see Bolhuis et al. 2011). There is a broad connection of the various neural structures in various psychological processes (Bolhuis et al. 2011). Thus, the human mind can work through more general cognitive procedures, which allows learning and problem solving in different environmental and social conditions (see Bolhuis et al. 2011). Moreover, Barrett (2012) argues that the mind can be composed of both general and specific modules. In this case, adaptations of the brain are flexible and can integrate, for example, mechanisms molded in paleoenvironments with mechanisms constructed during the ontogenetic development of the individual (see Barrett 2012).

Universal Human Nature (UHN)

It is assumed that the psychological mechanisms evolved in the human mind are responsible for producing a UHN, that is, a "typical species" (Tooby and Cosmides 2015). This characteristic of human beings is expressed through different environmental and social conditions (see Tooby and Cosmides 2015). In this sense, the main long-term objective of EP is the mapping of this UHN (Tooby and Cosmides 2015). However, the main criticism regarding the concept of UHN is the fact that behaviors observed in specific human populations are generalized to all populations (see Bolhuis et al. 2011). For example, many studies in EP are carried out with university students, considered a representative sample of human nature (see Bolhuis et al. (2011). In this case, universalism ignores aspects of ontogenetic development, since the environment will evoke genetically pre-determined responses (Bolhuis et al. 2011).

In investigating the evolution of human nature, it is important to integrate concepts and theories, such as Epigenetics and Niche Building Theory, which understand human beings as active constructors of their environments. In this sense, due to the diversity of environmental conditions, the person-environment interaction may have generated distinct adaptive responses during evolutionary history (see Bolhuis et al. 2011; Laland and Brown 2006).

Gradualism

The human mind has a set of genes coadapted to the ancestral environment that do not respond rapidly to the selective pressures of the current environment (Tooby and Cosmides 2005, 2015). Evolutionary processes are slow and need hundreds of generations to build a highly complex "mental" program. In this sense, human minds would still be adapted to the world of our ancestors (Tooby and Cosmides 2015). People commonly experience an adaptive delay when facing the challenges of industrialized societies, because these environments are different from the environment in which we evolved. For example, the taste for fatty foods is an adaptive behavior for ancestral environments, in which fat was scarce, but is non-adaptive in the current environment because it increases the incidence of cardiovascular diseases (Cosmides and Tooby 2003). However, there is evidence of recent major genetic changes in human populations that contradict gradualism (Bolhuis et al. 2011).

Perhaps one of the greatest shortcomings of EP is its failure to take into account the extent to which human activities can accelerate biological evolution by modifying or silencing certain genetically inherited predispositions (see Stanford 2019). For example, the inclination to favor open environments such as the savanna proposed by some EP studies is no longer observed in some cultures, which might result in the establishment of humans in different modern environments (see Moura et al. 2017, 2018). Furthermore, there is evidence that cultural practices may have influenced human evolution by altering selective pressures, resulting in the selection of specific genes. An example would be the increase over time of the frequency of the *CD72* gene and of other genes that improve malaria resistance in West Africa as a result of the adoption of agriculture, which exposed the populations in this region to this disease (see Laland et al. 2010; Santoro et al. 2017). In this way, the interaction between genes and culture has some influence on the evolutionary history of humans (Laland et al. 2010).

According Laland and Brow (2006), human beings have the capacity to modify the environment, that is, they modify the environment in which they live to suit themselves and with that they reduce the adaptive delay. These authors argue that there is an adaptive complementarity of the organism and the environment, with a dynamic interaction between natural selection and the construction of cultural niches. In this case, even if human beings are affected by cardiovascular diseases, they have the capacity to build hospitals or remedies to deal with these diseases (for a more complete argument, see Laland and Brown 2006).

Adaptive Memory: An Important Model for Evolutionary Ethnobiology

Based on the evolutionary psychology's perspective that the human mind has evolved to favor specific information to deal with the threats of ancestral environments (Tooby and Cosmides 2015), the adaptive memory model proposed by Nairne et al. (2007) describes the differential behavior of the human mind in a survival situation, suggesting that our memory system evolved through natural selection to prioritize information that is relevant to survival and reproduction. According to Nairne and Pandeirada (2008), this propensity of the human mind to favor this type of information originated as a result of the selective pressures of ancestral environments, and may have been of extreme relevance for early hominids to recall information such as feeding sites, predator action and partner behavior.

The experiments of Nairne et al. (2007) showed that when people were asked to imagine prey in an environment similar to a "African Pleistocene Savannah" without basic survival supplies, such as water and food, and having to avoid predators, they tended to better remember words that would be relevant to this survival scenario over other less critical scenarios, such as the "moving to a foreign environment" scenario.

Since then, the behavior of the human mind to prioritize information relevant to survival has been consistently debated in an emerging body of studies (see Nairne et al. 2007; Nairne et al. 2008; Nairne and Pandeirada 2008; Nairne et al. 2009; Nairne et al. 2012; Seitz et al. 2018), and several investigations have replicated the findings of Nairne and colleagues (Weinstein et al. 2008; Sandry et al. 2013; Yang et al. 2014), whether these investigations were conducted with people of different age groups (Nouchi 2012; Prokop and Fančovičová 2014; Broesch et al. 2014), or who live in different environmental contexts (Barrett and Broesch 2012; Prokop and Fančovičová 2014).

For example, in studying the recall of dangerous and non-dangerous animals, Barrett and Broesch (2012) found that children living in the city of Los Angeles in California and children in a Shuar village in the Ecuadorian Amazon presented high levels of recall when images and information on the name and diet of dangerous animals were presented. This result suggests that the human propensity to recall important information for survival may be innate in our species and, regardless of the environmental context in which people live, there is a human memory tendency to prioritize this information to the detriment of any other information.

Another interesting aspect that has generated controversy among some evolutionary psychologists is the fact that some studies defend the idea that the human capacity to recall this information is not necessarily tied to situations that refer to threats of ancestral environments. Yang et al. (2014) have observed, for example, that important words for survival were well remembered by people both in ancestral (pasture) survival scenarios and in non-ancestral /modern environments (mountains). In addition, Young et al. (2012) by testing human attention to threats, have noted that threats from modern environments—such as firearms and cars—also capture and maintain attention in the same way as would be expected for threats from ancestral environments—such as snakes and spiders. This suggests that the human capacity to recall adaptive information—threats that could compromise human survival and reproduction—may also be observed in people occupying distinct environmental contexts, regardless of whether this information is associated with a threat of ancestral environment—African savannah Pleistocene—in opposition to what some evolutionary psychologists still suggest. What is interesting in these findings is that they show that, although there are cognitive adaptations resulting from selective pressures, these are not hardwired to respond only to ancestral threats. This may be related to the human ability to adaptively respond to situations that can compromise their survival (for example, see the study by Silva et al. 2019).

Based on this perspective, Nouchi (2012), when comparing the effect of survival in the memory of young and old people, observed that by classifying words in a situation of survival and self-referral—which encourages participants to explicitly recover personal episodic memories—the participants tended to recall a greater amount of stimuli linked to the survival situation. According to Wixted et al. (2018), the episodic memories correspond to the recollection of past individual experiences that occurred at a particular time and place. This fact is interesting, since Nouchi's study (2012) reveals that the recall of information related to past personal experiences did not receive a better recall of people; on the contrary, there was a tendency to recall information associated with a survival context.

These results reveal some interesting insights when compared to other findings. Empirical studies have shown that past personal experiences with environmental catastrophes, for example floods, tend to receive more attention in people's memories (see Ruin et al. 2007), which leads us to think that episodic memories are intensified only in critical situations involving survival. Sousa et al. (2016), for example, when conducting a study in a rural community located in the Northeast of Brazil, observed that people tended to prioritize in memory information on medicinal plants used in the last year, which are also indicated as the most important. In this case, prioritizing in memory important resources

in medicinal use linked to recent previous experience may favor the survival of people in dealing with diseases.

Another important aspect is that human memory seems to behave differently when confronted with information relevant to health care. For example, Alqahtani et al. (2017) found that emerging infectious diseases, in which people were most susceptible to, such as Middle Eastern respiratory syndrome, received more attention in people's memories than mass catastrophes that occurred recently in the population.

In another study, Prokop et al. (2014) observed that information on parasitic diseases considered to be of adaptive relevance to humans were better remembered, rather than information on hormones, which were considered as irrelevant information in a survival situation. Besides that, Fernandes et al. (2017) observed that adult persons have a better recall of objects that have been described as being touched by people with serious diseases—transmissible or lethal—to the detriment of items described as touched by healthy people. This suggests that human memory may perform better when information relevant to health care is presented. Interestingly, the same information seems to emerge in remembrance when other survival-related information is being presented simultaneously (see Alqahtani et al. 2017).

In addition, it is noted that as humans are confronted with adaptive information that is related to the natural world, memory also seems to behave differently. For example, Prokop and Fančovičová (2014) found that children exposed to toxic and non-toxic plant information associated with fruit images of different stains that were associated to these plants—red and black = toxic, and green plants = non-toxic plants—the information of plants with fruits of black coloring was better remembered by the children due to the association with toxic fruits. Barrett et al. (2016) also observed that children of different cultures better recalled information about dangerous animals, followed by food and dangerous objects. These results may also be indicating that the human memory performs best when exposed to certain information about the natural world.

These findings appear to be consistent with the idea of a hierarchical memory proposed by Sandry et al. (2013). These authors studied the memorization of words in different scenarios related to adaptive mechanisms—survival, fear and phobia, selection of partners, avoidance of incest, detection of cheaters, jealousy, infidelity and gaining or maintaining status—and observed that the survival scenario excelled in word recall over all other adaptive mechanisms. The explanation found by Sandry et al. (2013) for this result is that this occurs because the survival scenario has a more general structure, that is, it can invoke all of these adaptive mechanisms simultaneously, and as a consequence manages to activate larger areas of the brain associated with memory, rather than a single adaptive mechanism in isolation—for example, only phobia. Therefore, it is likely that human memory functions hierarchically during recall of this information, that is, memory does not retain them equally. Thus, if human memory were a rigid system for prioritizing this information, all of them would be expected to present similar levels of recall.

In this case, it would be expected that in the study by Barrett et al. (2016), for example, people would similarly remember information about animals, food and dangerous objects, because all this information is important for survival. However, as noted by the authors, people tended to better remember information associated with dangerous animals than information about food and dangerous objects. This may be happening, as suggested by Sandry et al. (2013) because some of this adaptive information, for some unknown reason, may be prioritized in memory. Moreover, a relevant insight from the findings of Barrett et al. (2016) is that human memory may operate differently within the survival scenario when confronted with certain information about the natural world to the detriment of others that are also linked to survival.

Thus, it is likely that human memory functions hierarchically to recall this type of information (Fig. 1), and performs differently when this information involves the adversities of natural environments. This brings us to the idea of the existence of a *human naturalist mind*, apt to remember better this information to the detriment of any others. This memory behavior can be observed in several modern environmental contexts and in different cultures.

Insights from Adaptive Memory for Evolutionary Ethnobiology

An interesting fact that derives from the idea of adaptive memory concerns the understanding of how memory bias can affect people's relation to nature (Silva et al. 2017). Adaptive memory provides us with some important insights that can help evolutionary ethnobiologists to understand how human cognition works in the face of environmental challenges. Can an ethnobiologist question, for example, why people remember one food resource better than another? Why do people remember one particular medicinal plant better over another? How does remembering information that is important for survival affect the human's relationship to biota? These are just some of the inquiries that can be made using adaptive memory as background. In the following, we detail some theoretical insights that we consider important and that can serve as a basis for the development of studies in evolutionary ethnobiology.

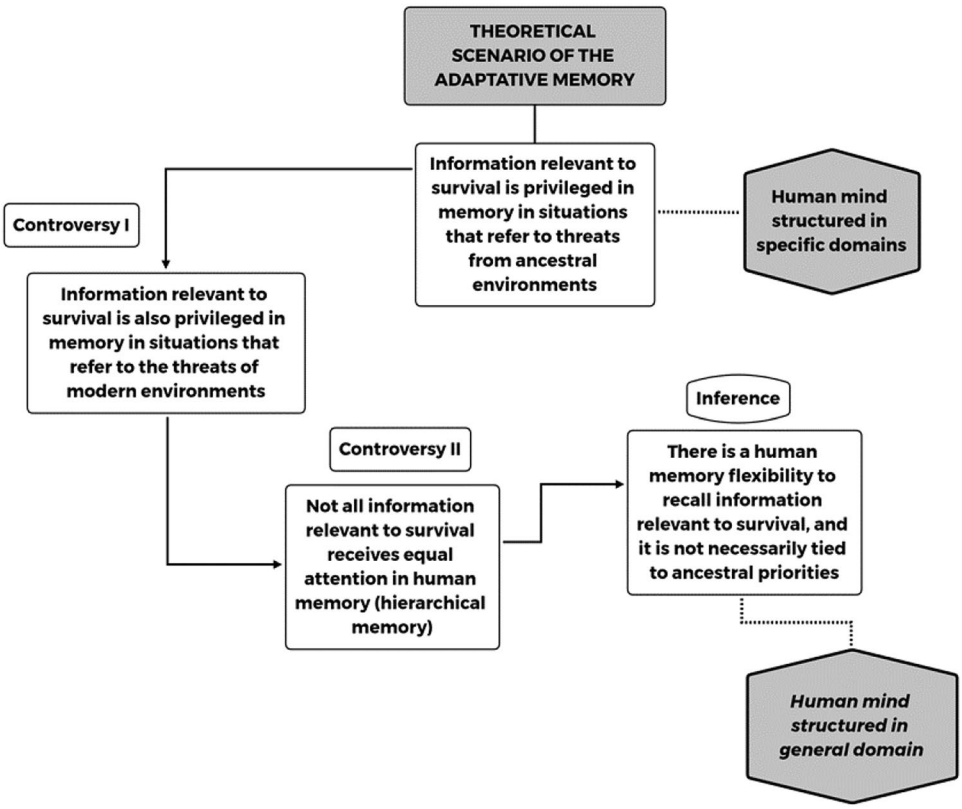

Fig. 1 Theoretical scenario of adaptive memory, controversies and possible inferences

Adaptive Memory is Observed in Different Environmental and Cultural Contexts

The adaptation of memory to privilege important information on survival is innate in the human species (Nairne et al. 2007), and the adversities of ancestral environments are not necessarily attached to it (Young et al. 2012; Yang et al. 2014). Such a mnemonic feature can be observed in different environmental and cultural contexts (see Barrett and Broesch 2012; Barrett et al. 2016; Sousa et al. 2016).

Adaptive Memory Functions Hierarchically

Human memory favors some information that are relevant for survival better than others (see Sandry et al. 2013; Silva et al. 2019). In addition, there is a tendency for memory to prioritize information related to challenges of natural environments to the detriment of other information that are also important for survival (see Barrett et al. 2016).

Humans have a Universal Naturalistic Mind

A greater retention in human memory of information relevant to survival occurs when it is associated with natural environments (see example in Barrett et al. 2016). It leads us to consider the existence of a universal human naturalistic mind (Albuquerque and Ferreira Júnior 2017). The naturalistic mind can be understood as a structure of cognition that has evolved in response to the adversities of different natural environments occupied by humans throughout the evolutionary process (Albuquerque and Ferreira Júnior 2017). The pressures of these different environments may have led the human brain to develop an effective cognitive and behavioral apparatus to solve more recurring natural challenges, that is, that present greater regularity in the environment (Ferreira Júnior et al. 2019).

This assumption may be the key to understand why certain information linked to the natural world is best remembered by humans.

Thus, we agree with the idea proposed by Barrett (2012) that our mental mechanisms may be heterogeneous, with new structures evolving from older structures, in a combination of ancestral characteristics with relatively recent characteristics. In this case, the cognitive adaptations observed in modern humans would not necessarily be products of responses to adversities imposed by a specific environment of the ancestral past, but may reflect the selection of general strategies of the human mind to meet challenges in diverse environments.

In summary, we believe that: (i) people remember important information for survival independent of their environment and culture; (ii) the ability to recall this information is not exclusively tied to ancestral priorities; (iii) adaptive information is remembered hierarchically; and (iv) we were

endowed with a naturalistic mind capable of promoting information about the natural world. By assuming these assumptions are true, we may investigate in EE studies, for example: what kinds of cognitive mechanisms may be involved in intensifying information that are relevant to survival in modern environments; what information about the natural world is prioritized in memory; what factors intensify recall; and how this may influence human behavior in relation to nature.

Frequency of Involvement and Previous Experience with Risk Events Act as Enhancers of Adaptive Memory in Social-Ecological Systems

Some empirical studies have pointed out that environmental variables, such as the frequency of involvement in a risk event, and life history, such as past personal experiences with a critical event, may intensify the recall of important information survival in human memory (see Ruin et al. 2007; Sachs et al. 2017; Scheideler et al. 2017). In addition, in the ethnobiological context, there is evidence indicating a possible influence of these variables on the recall of this type of information in social-ecological systems (see Sousa et al. 2016). This suggests the existence of a possible influence of the frequency with which environmental events affect people and previous experience with them as enhancers of this adaptive information in human memory in social-ecological systems. Therefore, we believe that the same variables that lead to prioritization in the memory of information to deal with a risk situation—frequency and previous experience—may also be the mechanisms responsible for interfering with human strategies to deal with the adversities of their environment. Santoro et al. (2015) have noted, for example, that people tend to select more species for the treatment of recurrent diseases in local medical systems. Another study by Santoro et al. (2017), also observed that the incidence of malaria affected the use of antimalarial medicinal plants in African human groups in periods when there were no public policies to control the disease. Therefore, this aspect may be indicative that the frequency of involvement of a risk event may intensify the recall of information in human memory. This may trigger greater efforts to solve it, leading to substantial modifications in the environmental niches that people occupy.

In addition, we believe that the changes generated in the environmental niches that people live and that may have originated from these same cognitive biases may also affect the recall of important information for survival. According to Silva et al. (2017), for example, the selection of a given medicinal resource through its advantages that are linked to the use within a local medical system can lead to cognitive biases that make information about this resource more memorable. Thus, a hypothetical example for such an assumption would be that people in dealing with recurrent illnesses would also tend to concentrate the resources needed to treat them near their homes—optimization advantages within the medical system—in this case, these resources become more memorable due to the influence of continuous and direct contact with it.

This discussion, combined with the evidence for hierarchical memory, may suggest that the naturalistic mind deals with environmental complexity by filtering information about survival, prioritizing those that affect it immediately, to the detriment of other information involving less immediate situations. This may explain both the evidence from ethnobiological studies involving recurrent diseases, and the behavior observed in hierarchical memory. For example, the fact that information about dangerous animals is more remembered than dangerous food (Barrett et al. 2016) may reveal the functioning of a mind that operates to deal with current situations. In the evolutionary past, identifying and fleeing a predator may have required a greater activation of memory-bound areas of the brain in order to respond immediately to this situation when compared to the identification of toxic foods (a situation that also affects survival, but less immediately). This may have been the evolutionary scenario of the naturalist mind, so that today it is reflected in the construction of social-ecological systems, directed to respond to recurring events.

Thus, understanding what kinds of variables interfere with the recall of adaptive information that involves the natural world may be the first step in understanding how the naturalistic human mind has evolved and operates in dealing with nature adversities, as well as the human behavioral patterns that can emerge from this relationship. Understanding these mechanisms may represent an important step in understanding human behavior in relation to biological resources, which is the focus of interest in evolutionary ethnobiology.

Final Considerations

Tracing the human evolutionary path is not an easy task, which may be why so many scientific disciplines talk to each other, and promoting this dialogue is one of EE's key missions (see Albuquerque and Ferreira Júnior 2017). This is a recent endeavor, which requires building bridges. For Stanford (2019), overcoming the barriers between psychology and the social sciences and between those sciences and those that study other organisms are key steps.

In this wise, it is difficult to assert, for example, that people's attitudes towards nature result only from genetic or cultural factors. Our advanced cognitive capacity seems to have evolved not only through genetic factors, but also through human practices, indicating gene-culture coevolution

(Altman and Mesoudi 2019; Stanford 2019; see also Albuquerque et al. 2019).

Considering that certain mental capacities must be present for a given culture or socio-ecological system to evolve (see Stanford 2019), ethnobiological studies that analyze human behavioral patterns without taking into account the evolutionary factors that precede a certain behavior may not completely capture this phenomenon. Thus, we believe that dialogue among the scientific disciplines that analyze the relationship between people and their environment is relevant for the growth of EE.

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