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# Public Awareness, Perception, and Acceptance of the Environmental Implications of Shale Gas Extraction on Water Resources: A Case Study of Zawia City

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# الوعي العام والتصور والقبول للآثار البيئية لاستخراج الغاز الصخري على الموارد المائية: دراسة حالة مدينة الزاوية

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**Abstract:**
Public perception assessment plays a significant role in understanding the development of shale gas and its impact on water resources. Shale gas is increasingly being produced as an alternative to conventional gas and oil in many countries due to its availability in various parts of the world. Shale gas extraction has the potential to contaminate groundwater due to the release of flow-back water during the extraction process and the deep injection of water containing a mixture of chemicals used in hydraulic fracturing. The substantial water requirements for this process could potentially impact groundwater supplies, which would have implications for ecosystems dependent on groundwater and other water uses. In Libya, substantial deposits of shale gas exist, and concerns regarding the potential environmental impact of shale gas extraction techniques such as hydraulic fracturing are growing. In this study, 304 residents in Zawia city, located in the northwest of Libya, were surveyed to gather their perspectives on the potential effects of shale gas development on the quantity and quality of water resources. The survey questions were categorized based on information, knowledge, awareness of technology used. Feedback and basic demographic and socioeconomic information of the respondents were collected through online and in-person surveys. The responses were analyzed using statistical and descriptive methods. The results showed that 40.3% of the participants expressed a perception that shale gas has a potential negative impact on water resources. It was also observed that some of the feedback varied depending on age, gender, and education level, while others were relatively

independent of these criteria. This study and future research in this field will contribute to shaping public opinion and policies related to the development of unconventional gas and oil.

**Keywords:** hydraulic fracturing, public perception, shale gas, water contamination.

**الملخص:**
يلعب تقييم إدراك الجمهور دورًا مهمًا في فهم تطوّر استغلال الغاز الصخري وتأثيراته على الموارد المائية. ويشهد إنتاج الغاز الصخري تزايدًا ملحوظًا في العديد من الدول بوصفه بديلًا للغاز والنفط التقليديين، نظرًا لتوافره في مناطق متعددة من العالم. وتنطوي عمليات استخراج الغاز الصخري على احتمالية تلوث المياه الجوفية نتيجةً لإطلاق المياه المتدفقة أثناء عملية الاستخراج، والحقن العميق للمياه المحتوية على مزيج من المواد الكيميائية المستخدمة في التكسير الهيدروليكي. كما أن المتطلبات المائية الكبيرة لهذه العمليات قد تؤثر سلبًا على مخزون المياه الجوفية، الأمر الذي ينعكس على النظم البيئية المعتمدة عليها، فضلاً عن مختلف استخدامات المياه الأخرى. في ليبيا، تتوافر احتياطيات كبيرة من الغاز الصخري، وتتزايد المخاوف بشأن الآثار البيئية المحتملة لتقنيات استخراجه، لا سيما التكسير الهيدروليكي. في هذه الدراسة، تم استطلاع آراء 304 من سكان مدينة الزاوية، الواقعة في شمال غرب ليبيا، بهدف استكشاف تصوراتهم حول التأثيرات المحتملة لتطوير الغاز الصخري على كمية ونوعية الموارد المائية. وقد صُنّفت أسئلة الاستبيان ضمن محاور تشمل المعلومات، والمعرفة، والوعي، والتقنية المستعملة. كما جُمعت آراء المشاركين إلى جانب البيانات الديموغرافية والاجتماعية والاقتصادية الأساسية من خلال استبيانات إلكترونية وميدانية. تم تحليل البيانات باستخدام أساليب إحصائية ووصفية، وأظهرت النتائج أن نسبة 40.3% من المشاركين يرون أن للغاز الصخري تأثيرًا سلبيًا محتملًا على الموارد المائية. كما لوحظ أن بعض الآراء اختلفت تبعًا لعوامل مثل العمر والجنس والمستوى التعليمي، في حين بدت آراء أخرى مستقلة نسبيًا عن هذه المتغيرات. ومن المتوقع أن تُسهم هذه الدراسة، إلى جانب الدراسات المستقبلية في هذا المجال، في توجيه الرأي العام وصياغة السياسات المتعلقة بتطوير موارد النفط والغاز غير التقليدية.

**الكلمات المفتاحية:** التكسير الهيدروليكي، تصورات الجمهور، النفط الصخري، تلوث المياه.

**Introduction:**

Shale gas has become an increasingly popular source of energy worldwide. Technological developments have led to the emergence of new energy sources, with natural gas recently becoming a significant energy source in many countries. This transition aims to decrease dependence on imported energy and strive for energy independence [1,2,3]. Shale gas can also be used as a substitute fuel. The reason for this is that unconventional sources of gas, including shale gas, which were once considered economically unfeasible to extract, have now become commercially viable due to technological advancements in extraction techniques such as hydraulic fracturing (fracking) and horizontal drilling. This has opened up new possibilities for utilizing shale gas as an alternative to conventional fossil fuels. [3,4]. Despite the economic advantages, the rapid growth of unconventional gas production has sparked a general debate about the potential impacts on the environment and human health, knowing that the observed consequences of shale gas development, as well as any potential environmental risks, have been identified and explained for a long time [5,6].

Extensive research and analysis, as documented in various studies and evaluations, have provided valuable insights into the various risks associated with shale gas [7, 8], with a specific focus on its impact on water resources [9]. Several significant concerns have emerged, including air pollution, ecosystem fragmentation, greenhouse gas emissions, radiation exposure, the potential for man-made induced seismic events, as well as the contamination of both groundwater and surface water [10,11,12]. With the exception of Russia, shale gas resources are abundant across Europe. However, in comparison to the United States, Europe faces the challenge of a higher population density and more stringent regulations governing oil and gas exploration [13].

Among the various aspects surrounding shale gas, hydraulic fracturing emerges as the most contentious issue. This technique involves the extraction of gas from impermeable shale formations through a combination of horizontal drilling and hydraulic fracturing. The process requires significant amounts of water, and the fracturing fluid used contains water, sand, and several chemical additives. The American Environmental Protection Agency (EPA) has identified over a thousand compounds as fracturing additives. Among these compounds, 27 have been confirmed or suspected to be carcinogenic or pose risks as pollutants of drinking water [14,15]. After drilling the well vertically to reach the depth of the shale layer, horizontal drilling is conducted [16, 17]. Any water remaining at the bottom of the well is considered consumptive waste, as it is no longer part of the hydrological cycle [18].

Figure (1) illustrates the main completion process, hydraulic fracturing drilling, which is employed to extract hydrocarbons from low-permeability, non-conventional reservoirs following the drilling of the wellbore. The utilization of hydraulic fracturing, commonly known as "fracking," has experienced exponential growth in the United States. [19]. Over time, the water consumption per well during the hydraulic fracturing process has significantly increased, leading to concerns about its potential impact on local water resources. The U.S. EPA (2016) acknowledges that the effects on groundwater can be substantial, although they depend on the balance between water withdrawals, resource availability, and recharge rates at specific locations [15, 20, 21]. In West Texas, the primary region for unconventional oil production in the United States, an average well consumed more than 14.6 million gallons of water in early 2017. To put this into perspective, this amount of water is equivalent to the daily water supply for 91,000 households of two people in the U.S., or approximately 250 households per year [21].

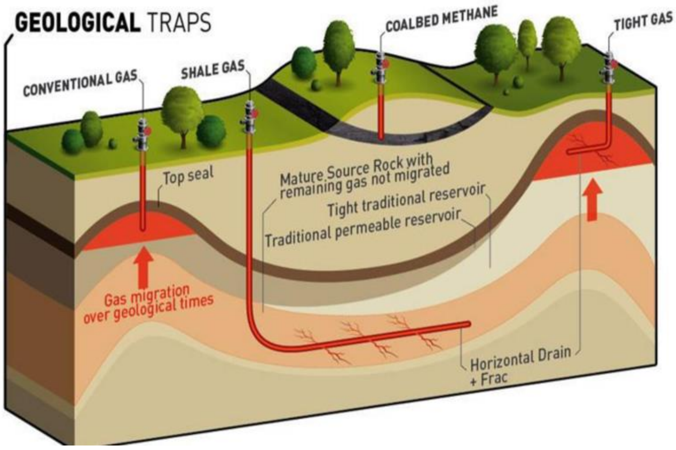


**Figure (1):** Schematic representation of the geological characteristics of natural gas resources.

The information depicted in the figure is sourced from the U.S. Energy Information Administration (EIA) in 2010. The increased production of natural gas from shale gas basins in the United States has raised concerns about potential environmental impacts, particularly the contamination of shallow drinking water basins [22]. Several aspects related to the safety of shale gas extraction and hydraulic drilling have been identified as areas of concern, including the migration of stray gas to shallow groundwater [23], hydraulic interconnections between shale formations and shale aquifers [24], shale water use [25], and the composition of hydraulic fracturing fluid and brines containing harmful chemicals during drilling, transportation, and disposal [24, 25]. It is worth noting that shale gas exploration is projected to expand globally, with new initiatives and explorations taking place in countries such as China, Germany, Poland, Australia, and New Zealand. Therefore, field-based studies and their findings are crucial for conducting a comprehensive global assessment of the environmental risks associated with shale gas drilling and hydraulic fracturing [26].

Demand for fresh water is growing worldwide, it is crucial to recognize that water is vital for various aspects of human well-being, development, and the preservation of healthy ecosystems. In this context, Libya stands out as one of the most water-stressed nations globally. The majority, over 98%, of Libya's water consumption relies on groundwater, making it the country's primary water source [27, 28]. In Libya, two primary types of groundwater sources exist: shallow aquifers and deep aquifers. Shallow aquifers are replenished by rain and surface runoff, making them renewable, whereas deep aquifers are non-renewable [27]. As a result, water resources in Libya must be carefully assessed, as significant developments in the energy industry are likely to have an impact on them at different levels. Furthermore, there is a growing global water shortage, with many regions experiencing water scarcity. This includes physical water scarcity, where more than 75% of surface water is utilized for various purposes, as well as economic water scarcity, where surface water may be abundant but lacks the economic means for efficient utilization [29].

Simultaneously, groundwater reserves are being depleted and diminishing in various regions worldwide. The consequences of excessive groundwater extraction are estimated to be 3.5 times larger than the current aquifer size, with an estimated 1.7 billion people residing in areas where groundwater resources and/or groundwater-dependent ecosystems face threats [30]. In particular, hydraulic fracturing poses risks concerning both water quality and quantity [14]. Hence, one of the most contentious and heavily debated issues is the impact of flow-back during the fracturing process on water resources. Additionally, certain studies have indicated that the risks associated with wastewater disposal from shale gas production, along with the associated uncertainties, outweigh the risks related to water resource contamination [31]. The challenge of wastewater emerges as soon as drilling commences, particularly after hydraulic fracturing. Examples of waste gases generated during shale gas production operations include drilling muds, flow-back, and produced water or brine. The management options for wastewater vary and are influenced by factors such as infrastructure, shale gas production economics, and the political and social environment of the specific region [31, 32, 33]. Libya holds significant prominence as a hydrocarbon producer in North Africa. Within Libya, there are three major shale gas basins: the Ghadames (Berkine) Basin in the west, the Sirt Basin in the central region, the Murzuq Basin in the southwest, and an additional basin, the Kufra Basin, situated in the southeast [34], as depicted in Figure (2).

However, one of the most pressing challenges facing Libya presently is the lack of water. Consequently, this study focuses on exploring one potential environmental consequence of unconventional gas development, specifically its impact on water resources. Furthermore, understanding public attitudes towards energy sources such as unconventional hydrocarbons is essential for fostering broader societal discussions regarding the options and choices that can contribute to more sustainable and socially acceptable energy systems in the future. It is important to consider that a technology deemed socially acceptable may not necessarily be the most sustainable option for society in the short or long term [35].

**Methodology:**

**Study area:**

The survey was conducted in the city of Zawia, as shown in Fig. (2). Zawia city is situated 47 km west of the capital, Tripoli, on the Mediterranean coast in the northwest of Libya. It is noteworthy that Zawia City is home to an oil refinery, which was a significant factor in selecting it as a relevant context for the study. The refinery primarily engages in refining crude oil, producing asphalt, and blending and packaging mineral oils. In addition to supplying some oil derivatives needed by the local market, crude oil also flows through the oil port.) Additionally, the city of Zawia plays a significant role in the operations of the oil installations, involving active participation from the local population. This involvement has had a mixed effect on the local populace, but it has also supported the credibility of the notion that shale gas investment in Libya is viable. The selection of Zawia as a focal point is based on its theoretical relevance in understanding the potential advantages and risks associated with oil ventures in general.


**Figure (2):** The geographical distribution of onshore sedimentary basins in Libya, along with the proven discovered potential. This information is sourced from Hallett and Clark-Lowes in 2016.

**Data collection:**

The methodology employed aimed to analyze and assess the perspectives of the citizens regarding the potential impacts of shale gas extraction on water resources within the local context. A total of 304 individuals from Zawia were surveyed between December 1, 2019, and March 1, 2020. Participants were selected randomly to ensure a representative sample and to track public awareness of the effects of shale gas production on water resources. A set of questions was developed to measure public opinion on the short and long-term effects of the extraction process. Both online and paper surveys were conducted, and participants were provided with concise general information to avoid influencing their opinions. The selection of specific elements included in the survey questions was based on previous research and the experiences of other nations with hydraulic fracturing. All subsequent analyses were performed using IBM SPSS Statistics version 23 (2015), and the analysis adhered to qualitative data analysis standards.

**Results and discussion**

**Demographic Characteristics**

Previous studies have revealed conflicting effects of age, income, and education on people's perceptions of the shale gas development [36]. The most widely utilized demographics to forecast public opinion about shale gas development are age, gender, education level, and family income. The demographic characteristics of the sample population are as follows: The sample consists of 59.9% females, While the average monthly income ranges from 751 LD to 3000 LD. However, specific income distribution within this range is not mentioned. The majority of the sample is well-educated, with a range of educational attainment from high school to postgraduate education. Approximately 21.5% of the sample are high school graduates, while 68.6% are postgraduate graduates. It's important to note that these demographic characteristics are specific to the sample population described in the study. This information is showed in Table 1.

**Table (1):** Demographic Characteristics of Respondents

| **Age group** | |
|---|---|
| 18-24 | 48.7% |
| 25-34 | 21.5% |
| 35-44 | 14.2% |
| 45-54 | 10.3% |
| 55-64 | 4.3% |
| ≥ 65 | 1% |
| Gender | |
| Male | 40.1 % |
| Female | 59.9 % |
| **Monthly Family income** | |
| Less than 750 | 39.5% |
| 751-950 | 25.7% |
| 951-1200 | 10.9% |
| 1201-1500 | 13% |
| 1501-2000 | 8% |
| 2001-3000 | 2.8% |
| **Education level** | |
| Primary | 6% |
| High School Graduate | 21.5% |
| Some College or Technical School | 6.3% |
| College Graduate | 58.6% |
| Graduate or Professional Degree | 7.3 % |
| Not sure | 0.3% |
| **marital status** | |
| Single | 53.7 % |
| Married | 41 % |
| Divorced | 3.3% |
| Widowed | 2% |

**Knowledge of shale gas and hydraulic fracturing:**

Knowledge of shale gas and hydraulic fracturing is supported by previous geological, geochemical, and basin modeling studies conducted by the National Oil Corporation of Libya (NOC) and other researchers. These studies have indicated the presence of multiple layers of shale gas formations, ranging from Cretaceous in the Sirt Basin to Silurian and Devonian in Ghadames, Murzuq, Sirt, and Kufra basins [37]. This information is depicted in Figure 2. In this study, the degree of knowledge about shale gas and comprehension of the hydraulic fracturing procedure among respondents were examined. The majority of participants (58%) reported having a good knowledge of shale gas. Figure 3 illustrates the level of public knowledge on shale gas. Regarding the hydraulic fracturing process, the mean knowledge was estimated to be 1.42% (Figure 4), with a standard deviation of 0.494. Conversely, 43.7% of respondents stated they had a good understanding of the hydraulic fracturing process, with a standard deviation of 0.903 and a mean of 2.66. It is important to note that these results are specific to the study conducted in the city of Zawia and may vary in other regions or studies.

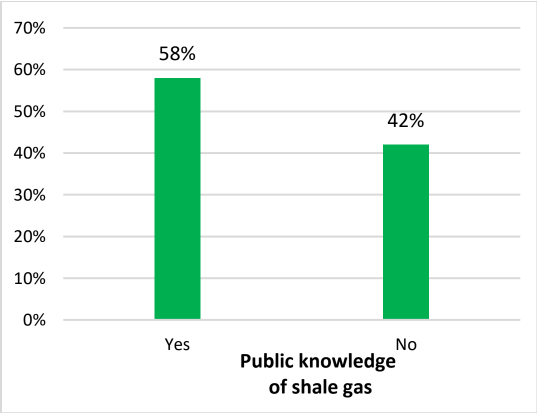


**Figure (3):** The Public knowledge of shale gas

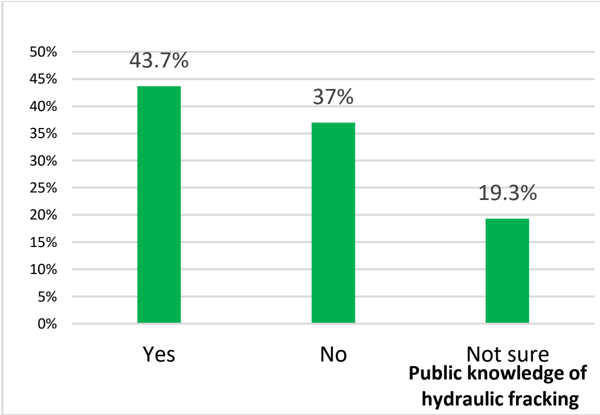


**Figure (4):** The Public knowledge of hydraulic fracking

**Public perceptions of regulation, decision-making and the institutions responsible for development**:

As shale gas emerges as a new energy source, it becomes crucial to comprehend and regulate both its benefits and risks. This understanding is necessary to prevent any negative impacts, address public concerns, and maximize the advantages associated with shale gas extraction. It is recommended that regulations cover all stages of the extraction process, ensuring that hydraulic fracturing is conducted safely and in an environmentally responsible manner to safeguard natural resources. According to the findings of this study, a significant majority of respondents in the city of Zawia, amounting to 92.6%, believe that specific rules and regulations should be established for shale gas development. The mean value for this response was 1.07, with a standard deviation of 0.263. It is important to note that these results are specific to the study conducted in the city of Zawia and may vary in other regions or studies.

**Risk and benefit perceptions:**

The extraction of shale gas through the process of injecting a fluid at high pressure into shale formations is associated with various potential hazards and risks, which have become subjects of intense public controversy. These hazards can arise as natural and social systems respond in sometimes unexpected ways. This study aimed to examine public perceptions regarding the risks of hydraulic fracturing, and it concluded that 45% of participants expressed a positive view of hydraulic fracturing's benefits, while 23% considered it to be negative, as depicted in Figure 5. Additionally, to assess the perceived level of risk associated with shale gas, another survey question utilized a response range of 1 (indicating no risks) to 10 (representing severe hazards). Figure 6 demonstrates that over 40% of respondents rated hydraulic fracturing as having no negative impacts on the local environment. However, it is noteworthy that 29.6% of respondents expressed moderate concerns regarding the dangers associated with shale gas.

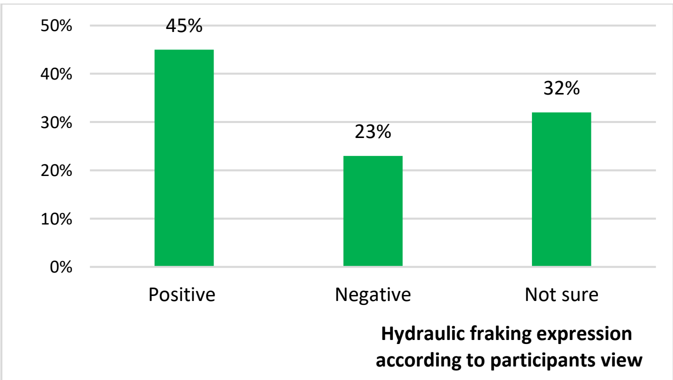


**Figure (5):** Hydraulic fracking expression according to participants view

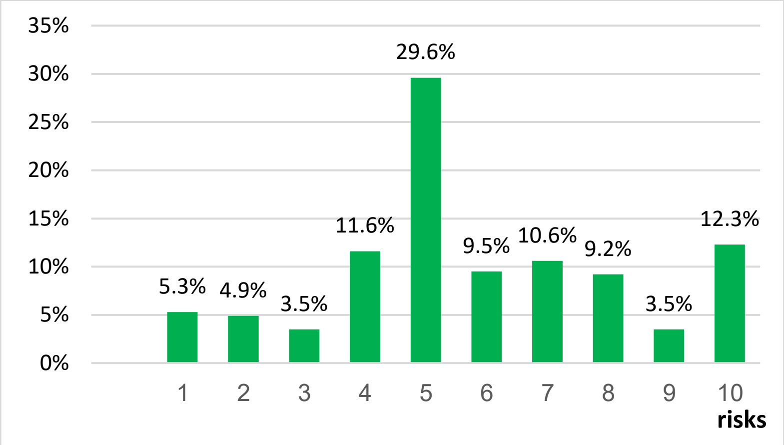


**Figure (6):** The risk views on a scale of 1 (no risks) to 10 (severe hazards).

**perception of potential shale gas impact on water resources:**

Recently, there has been a growing awareness of the water crisis in Libya due to several reasons, including excessive use of groundwater, increasing water demand, and the uncertain future of the Great Man-Made River Project (MMRP) due to its unstable state. Moreover, the maintenance required to continue extracting groundwater from the Sahara aquifer and transporting it through pipelines to the coastal cities in the north poses impossible challenges [27]. Consequently, assessing the risks associated with water resources becomes a daunting task. Previous studies consistently highlight one of the most significant potential consequences of shale gas extraction: its impact on water resources. When examining public perceptions regarding the potential adverse effects of shale gas on water quality and quantity, the study reveals that 40.3% of the respondents express concerns about the negative potential impact of shale gas on water resources.

**Conclusion:**

Considering the previous analysis of the respondents' familiarity with the potential impacts of hydraulic fracturing on water resources and taking into account the current state of water issues, it is evident that water scarcity poses a significant hindrance to economic growth. This problem is particularly pronounced in arid regions of Libya and globally. The findings of this study demonstrate a high level of awareness regarding shale gas and hydraulic fracturing. Some individuals are praising hydraulic fracturing as a transformative force that will enhance energy independence, generate employment opportunities, and lower energy expenses. More importantly, although public opinions regarding the impact of the shale gas extraction process on water resources are mixed, respondents in this study demonstrate a good level of awareness regarding the adverse effects of shale gas fracturing on water resources.

In fact, similar to other environmental risk issues that have been extensively debated, the discussion surrounding hydraulic fracturing (HFR) has been marked by uncertainty and confusion, largely due to a lack of transparency in water resource management. The views expressed by the respondents strongly support the implementation of appropriate shale gas regulations that align with environmental laws. Although having stringent regulations in place is crucial, their effectiveness hinges on their proper implementation, which requires significant investments of time and resources. Another important aspect that emerged from the results is the need for further clarification of terminology and concepts related to hydraulic fracturing. Such clarification is essential to promote more productive and informed discussions and to establish appropriate policy frameworks concerning energy, the environment, and water resources.

Therefore, the gas sector and regulatory bodies should actively encourage research endeavors aimed at improving management techniques. While there is always a possibility of water contamination during industrial processes, this risk can theoretically be minimized by adhering to best practices throughout the shale gas water cycle. Hence, it is necessary to remain abreast of emerging technologies and provide guidance for future scientific research activities aimed at expanding our understanding of the factors that influence the frequency and severity of potential impacts on drinking water resources resulting from activities within the hydraulic fracturing water cycle. For instance, future efforts could involve monitoring surface and groundwater in regions with hydraulic fracturing oil and gas wells. Additionally, it is essential to employ effective management strategies for wastewater and address these concerns to prevent any negative environmental legacy.

Overall, it is recommended that fracking projects be subject to comprehensive Environmental Impact Assessment (EIA) requirements to encompass their full scope. It is worth noting that these results may be subject to change due to various factors, and while these studies contribute to stimulating discussions and insights into public opinions on water issues, it is acknowledged that public opinions are dynamic and can evolve over time in response to different events. While we acknowledge that several factors can influence these results, we believe that these studies are valuable in initiating discussions and providing insights into public opinions on water issues. It is important to recognize that public opinions are inherently dynamic and can evolve over time in response to various events and circumstances.

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