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REPRODUCTIVE BIOLOGY OF FEMALE *PARAPENAEUS LONGIROSTRIS* (CRUSTACEA, DECAPODA, PENAEIDAE) IN THE NORTHERN TYRRHENIAN SEA (WESTERN MEDITERRANEAN)

Abstract - Aspects of the reproductive biology of female *Parapenaeus longirostris*, were analysed from monthly samples collected by trawling in the northern Tyrrhenian Sea, from January 1994 to February 1995. Ripe females were found all the year round and two peaks of activity were observed, one in spring and another at the beginning of autumn. All post-moulting females presented spent or post-spawned ovaries, therefore at least one ovarian cycle occurs with a single inter-moult period. The minimum female size at maturity was 16 mm carapace length (CL) and 50% of the female population was mature at about 22 mm CL. Fecundity ranged from 23 000 to 204 000 eggs respectively for individuals from 26 to 43 mm CL.

Key words - *Parapenaeus longirostris,* Crustaceans, Reproduction, Fecundity, Western Mediterranean.

Riassunto - *Biologia riproduttiva di femmine di* Parapenaeus longirostris *(Crustacea, Decapoda, Penaeidae) nel Mar Tirreno Settentrionale (Mediterraneo Occidentale).* L'analisi di campioni mensili del gambero rosa, *Parapenaeus longirostris*, raccolti da gennaio 1994 a febbraio 1995 sui fondi strascicabili del Tirreno settentrionale, ha permesso di definire alcuni aspetti della biologia riproduttiva di questa specie. Femmine con ooociti prossimi alla deposizione sono state trovate tutto l'anno, ma principalmente in primavera e all'inizio dell'autunno.
Tutte le femmine in postmuta presentavano ovari in riposo o in postdeposizione: questo particolare indica che il loro ciclo ovarico ha luogo entro un unico periodo di intermuta. Femmine con ovari maturi sono state trovate a partire dalla taglia di 16 mm di lunghezza carapace (LC), ma il 50% della popolazione femminile diventa sessualmente matura a circa 22 mm LC. Il numero di oociti prodotto dalle femmine dipende dalla loro taglia, e varia da 23.000 a 204.000 uova rispettivamente per gli individui compresi tra 26 e 43 mm LC.

Parole chiave - *Parapenaeus longirostris,* Crostacei, Riproduzione, Fecondità, Mediterraneo occidentale.

INTRODUCTION

The deep-water rose shrimp *Parapenaeus longirostris* (Lucas, 1846), is commercially important in a number of Mediterranean and Atlantic countries (Massuti, 1959; Arena and Li Greci, 1973; Holthuis, 1980). Its vertical distribution ranges from 20 to 700 m depth, but it is mostly caught over muddy or muddy sand bottoms between 70 and 350 m depth (Ghidalia and Bourgois, 1961; Heldt, 1954; Mori *et al.*, 1986; Tom *et al.*, 1988; Ardizzone *et al.*, 1990). Ghidalia and Burgois (1961) found that the distribution of *P. longirostris* was restricted largely to water masses with a temperature between 14 and 15 °C. Bombace (1972) recognised off western Sicily a *P. longirostris* facies between 150-350 m depth and related it to the presence of water masses of Atlantic origin (14 °C). However, the eastern mediterranean population is found in shallower and warmer waters (Tom *et al.*, 1988).
A size related bathymetric distribution can be found in this species. Juveniles principally settle at around 100 m of depth, although they can be also detected at 300 m, whereas the larger individuals are always found in water deeper than 350 m (Froglia, 1972; Mori *et. al.*, 1986; Ribeiro Cascalho and Arrobas, 1987; Tom *et al.*, 1988; Ardizzone *et al.*, 1990).
The main spawning area in the Northern Tyrrhenian Sea was found between 150 and 300 m depth, i.e. coinciding with the major distribution of the adults (Mori *et al.*, 1986). The reproductive activity of female *P. longirostris* was investigated by a number of authors (Heldt, 1938; Crosnier *et al.*, 1970; De Ranieri *et al.*, 1986; Ribeiro Cascalho & Arrobas, 1987; Tom *et al.*, 1988; Arculeo *et al.*, 1993; Sobrino and Garcia, 1994), but the results are conflicting. The fecundity of this species was recorded by Heldt (1938) who did not relate it to female size. This Author also described in detail the morphology of both the male and female reproductive system.
In this paper we elucidated the reproductive season, the size at sexual maturity and the fecundity of the females of deep-water rose shrimp *P. longirostris,* which knowledge is important for the management of its fisheries in the northern Tyrrhenian Sea.

MATERIALS AND METHODS

Field observations

Reproductive activity was studied in samples collected monthly from January 1994 to February 1995 off the northern Tyrrhenian Sea (Tuscany Archipelago, Western Mediterranean) at depth ranging from 60 to 540 m, the full bathymetric range of the species in the

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area. Sampling, more concentrated in the reproduction area of the species (bottoms ranging between 150 and 350 m of depth), was conducted during day-time hours by commercial bottom trawlers equipped with a 40 mm mesh-size cod-end. A total of 2937 females of *P. longirostris* were collected, ranging from 11 to 46 mm carapace length (CL), ovarian development and moult stage were recorded from each female. Carapace length (CL), recorded as the linear distance between the postorbital margin and the median posterior edge of the carapace was measured to the millimetre below. Four female maturity stages were defined, modifying the scale proposed by De Ranieri *et al.* (1986): Stage I, immature (translucid) or spent or post-spawned ovaries (whitish); Stage II, developing ovaries (yellow-cream); Stage III, advanced ovaries (pale green or green-grey); Stage IV, ripe ovaries (olive-green). Only two moult stages were considered: inter-moult, when the exoskeleton of the specimens was completely calcified; and post-moult, when the exoskeleton was soft, and weakly or moderately calcified.

Laboratory work

The size at which 50% of the females reached maturity was estimated using a logistic equation associated with a statistical program («Fishparm», Prager, 1987), and evaluating the fitted equation to determine the size corresponding to 50% mature. The logistic curve was fitted using two criteria (Sobrino and Garcia, 1994): in the criterion 1, the percentage of mature individuals present in the population (stage II plus stage III plus stage IV) was plotted against each size class; in the criterion 2 the same method was applyed, but considering matures only the specimens in stage III and IV. The size at 50% maturity was estimated by pooling either all samples of 1994 or those collected during previous surveys performed during 1986, 1987, 1991, 1992 and 1993. In this work, the first maturity size in the months of maximum spawning has not been estimated, because according to Bergmann's law (see Casanova, 1981), the slower development during the winter months produces a larger reproductive size, for that the individuals born in autumn-winter could reach an adult size through a larger number of moults than those born to the beginning of the summer.

Fecundity were estimated from the ovary of 31 ripe females ranging 26-43 mm CL, collected in April 1994. Ovaries were removed and stored separately in Gilson solution. The separated oocytes were dried at 60 °C, and weighed to the nearest 0.1 mg. Two estimates of fecundity were obtained for each female by dividing the weight of entire mass of separated oocytes by the weight of 5000-7000 oocytes sub-sample. Fecundity was then estimated as the mean of two estimates. If the variation between the two estimates was greater than 5%, the process was repeated. The parameter values of the relationship oocyte number-female size was estimated by the least-square (Model I) method (Sokal and Rohlf, 1981) using log-log transformation of the data, because according to Somers (1991) the use of the log-log model for size-specific fecundity is more suitable because the logarithmic transformations stabilise the variance in fecundity.

RESULTS

Figure 1 shows the female reproductive activity of *P. longirostris* performed over the period January 1994-February 1995. Ripe females were found throughout the year with two maxima of activity, one in spring and another at the beginning of autumn.

The percentage of post-moulting females (Figure 2) increased from January to August, decreased from September to October and rose from November to December. Most post-moulting females were found with ovaries at stage I. No recently moulted females were found with developed ovaries (i.e. at the stages II, III or IV). Only two specimens with soft exoskeleton, of 36 and 40 mm CL, caught in April showed developing ovary (stage II).

The smallest females with ripe ovary had 16 mm CL. The size at onset of sexual maturity (CL_{50}) estimated for different years using criterion 1, is shown in Figure 3; values ranged from 24.4 mm in 1993 to 19.5 mm in 1994. Figure 4 shows those obtained using criterion 2:

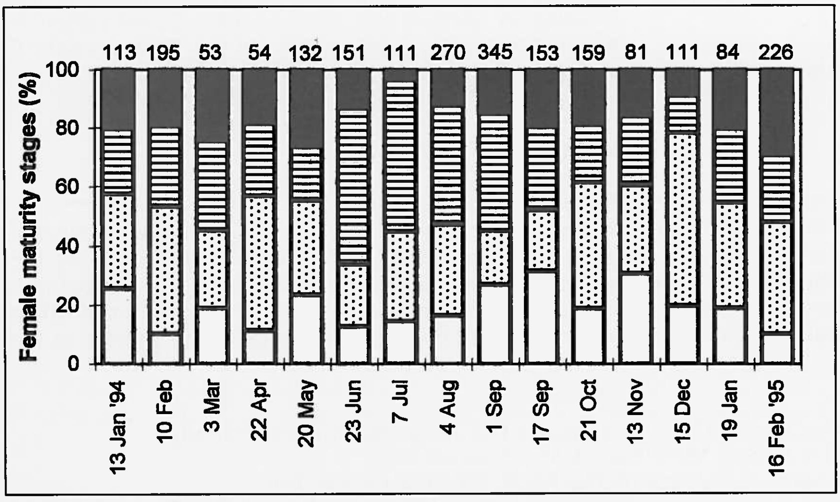

Fig. 1 - Reproductive activity of mature females of *P. longirostris* in the period January 1994-February 1995. The percentages have been calculated starting from the specimens ≥ 22 mm CL. Sample size is given above each histogram. White: immature or post-spawned ovaries; dotted: developing ovaries; lines: advanced ovaries; black: ripe ovaries.

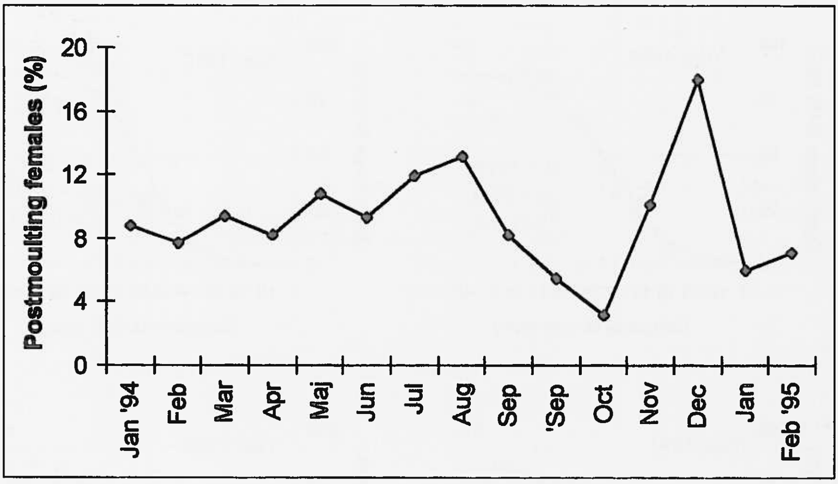

Fig. 2 - Percentage of post-moulting females in *P. longirostris* in the period January 1994-February 1995.

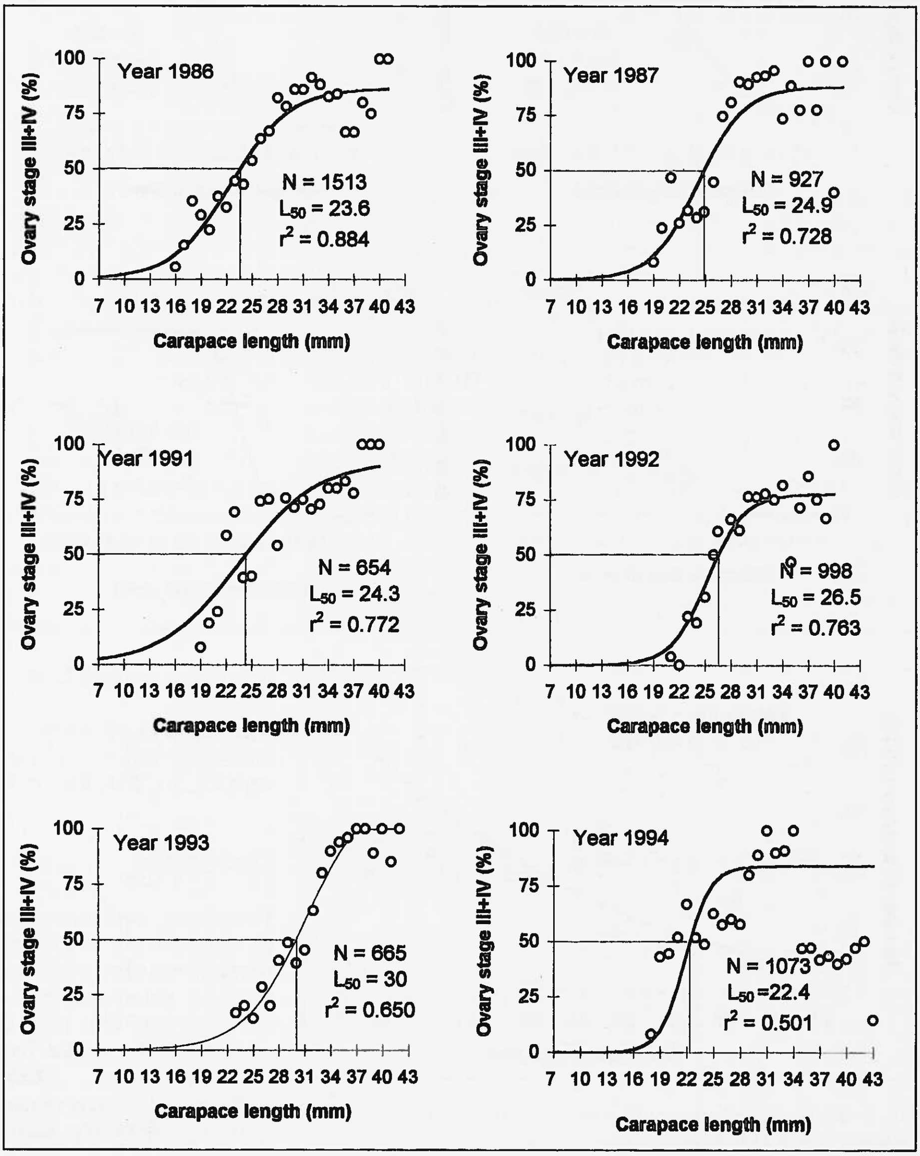

Fig. 3 - Size at 50% maturity for *P. longirostris* of the Northern Tyrrhenian Sea estimated for different years using criterion 1.

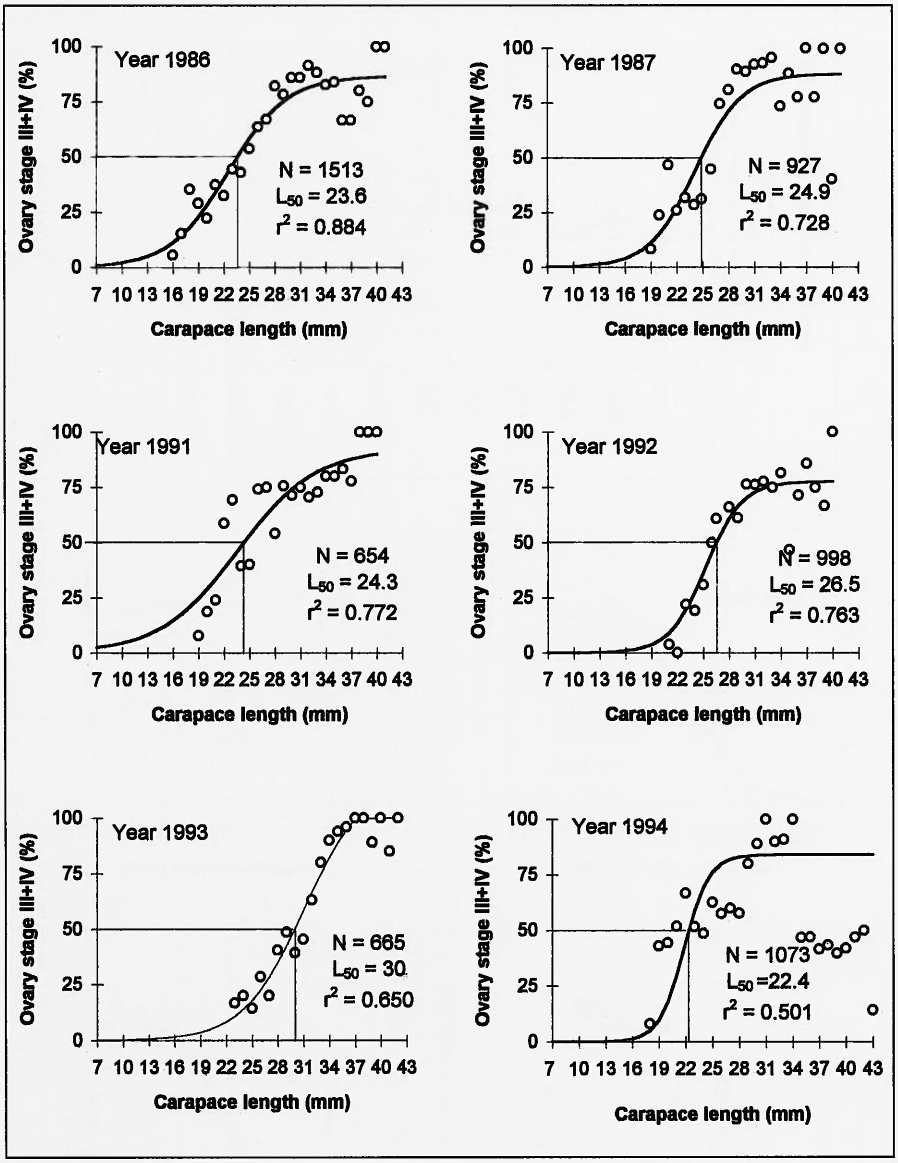

Fig. 4 - Size at 50% maturity for *P. longirostris* estimated for different years using criterion 2.

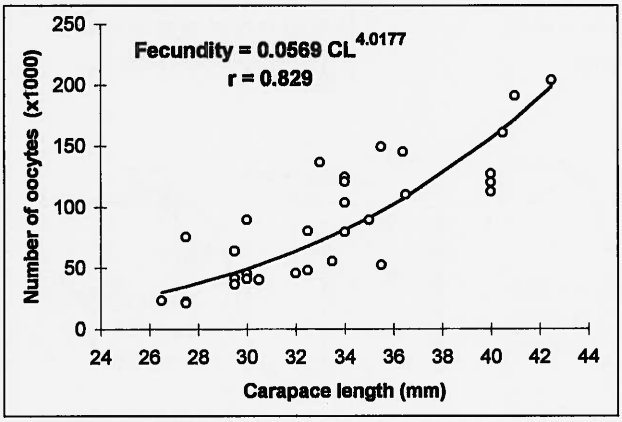

Fig. 5 - Relationship between the number of oocytes (fecundity) and carapace length in *P. longirostris*.

the value ranged from 23.6 mm in 1986 to 30 mm in 1993.

The number of oocytes in the ovary was related to the size of females, and ranged from 23000 oocytes at 26 mm CL to 204,000 at 43 mm (Figure 5).

Discussion

Fecundity and size at sexual maturity of crustaceans is required for the determination of a minimum commercial exploitation size (Jewett *et al.*, 1985). The positive relationship found here between the number of eggs and the size of females is consistent with observations made from other species of penaeids (see Dall *et al.*, 1990). Moreover, the value of r^2 demonstrated that carapace length (CL) is a good estimate of fecundity, since it explained 69% of the total variance. Heldt (1938) estimated for *P. longirostris* a fecundity of 150,000 to 400,000 oocytes per female, however, she did not report the size of the sampled females.

The percentage of post-moulting females followed well the trend of their reproductive activity. No recently moulted female *P. longirostris* was found with developed ovaries, therefore ovarian development and the spawning occur, probably during an inter-moult period in *P. longirostris*. Since the spermatophore is lost at each moult, mating should occur number of times during the adult phase, as already described for different species of penaeids (Crocos and Kerr, 1983; Dall *et al.*, 1990). Peneids are divided into closed thelycum species, in which mating take place immediately after ecdysis and open thelycum species, in which mating is accomplished just before spawning. *P. longirostris* is a closed thelycum species, therefore, probably mate at post-moult (Heldt, 1938). This hypotheses, however, seem to be in contrast with Heldt's (1938) observations, which describe that in female *P. longirostris* the spermatophores are not enclosed in a protective secretion. This fact suggested to Dall *et al.* (1990) that such species requires impregnation within hours from spawning. Then, in *P. longirostris* the fertilisation would be independent of the moulting process. Such subject poses questions for future research.

The smallest mature female was recorded by Ribeiro Cascalho and Arrobas (1987) in Portugal in the 24 mm size class. Off the Congo, Crosnier *et al.* (1970) found 16 mm to be the minimal size, while in Israel it was found to be 15 mm (Tom *et al.*, 1988). The presented value of 16 mm CL agrees with the values found by the two last authors.

First maturity sizes varied from 19.5 to 30 mm CL, depending on the criterion used. Other Authors obtained different values (see Sobrino and Garcia, 1994). Comparisons of the first maturity size from different studies must be viewed with caution, however, because such values may be greatly influenced by sample size and composition. As in *P. longirostris* the ovarian development and the spawning occur during an inter-moult period, it is possible to utilise the criterion 1 for estimating its size at first maturity. Thus, the first maturity size in *P. longirostris* of the northern Tyrrhenian Sea may be estimated at about 22 mm CL. This value is near to those reported by Crosnier *et al.* (1970) off the Congo and by Sobrino and Cardenas (1991, in Sobrino & Garcia, 1994) off Angola, 22 and 21.6 mm, respectively.

The reproductive activity of the female *P. longirostris* seem to vary among different geographical areas. Heldt (1938) reported November-April as the reproductive season of *P. longirostris* in Tunisian waters. In the Atlantic coast, off Congo, Crosnier *et al.* (1970) found reproductive activity from September to May with a peak in April, while off the Moroccan coast, Sobrino and Garcia (1994) found continuos spawning throughout the year, with two maxima of activity, in June and in October. On the coast of Egypt *P. longirostris* females develop ovaries in spring (Drobisheva, 1970, in Tom *et al.*, 1988). In the northern and southern Tyrrhenian Sea, respectively, De Ranieri *et al.* (1986) and Arculeo *et al.* (1993) hypothesise a major reproductive activity in winter and spring. Mature females were found in Portugal all over the year, but mainly in June-July and October-December (Ribeiro Cascalho and Arrobas, 1987). In Israel, the female population presented a reproductive activity throughout the year in shallow waters (47-73 m), while in deep waters they showed an arrest of the reproductive activity during June to August (Tom *et al.*, 1988). On the basis of the data relative to the recruitment of young animals to the benthos, Ardizzone *et al.* (1990) hypothesised for *P. longirostris* a single winter spawning. Our data is in agreement with Ribeiro Cascalho and Arrobas (1987), Tom *et al.* (1988) and Sobrino and Garcia (1994). Small differences could be due to the different hydrographical characteristics of the areas, but in general the reproductive activity of *P. longirostris* in the whole area of its distribution seems to be continuous during the year, with two maxima of activity, one in spring and another at the beginning of autumn.

In the eastern Atlantic, Crosnier *et al.* (1970) found a correlation between decreasing reproductive activity and temperature decrease from 18 °C to 15 °C, while in Israel, according to Tom *et al.* (1988), temperature lower than 16 °C is responsible of the decreasing of reproductive activity. In the northern Tyrrhenian Sea the temperature below 180 m depth is almost constant throughout the year (13.5 °C - Aliverti *et al.*, 1968), therefore it does not seem to be a limiting factor for the reproductive activity of *Parapenaeus,* at least in this sea. According some Authors (Boolootian *et al.*, 1959; Reese, 1968; Giese and Pearse, 1974) the breeding cycles are adapted to the availability of food for larvae, whereas there are no obvious correlation between these cycles and temperature, or adult food requirements. In contrast, Rokop (1977) observed that the food is related to gametogenesis in that it is necessary for gonad development and its abundance could act as a stimulus to spawning. The vertical circulation of water in the North Tyrrhenian Sea, which is one of the most important factors affecting phyto and zooplancton productivity, i.e. food for the shrimp larvae, is absent during the summer (Astraldi *et al.*, 1995: Innammorati *et al.*, 1995). Thus, the up-welling might be a limiting factor for the reproductive activity of *P. longirostris*. Also this aspect poses questions for future research.

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